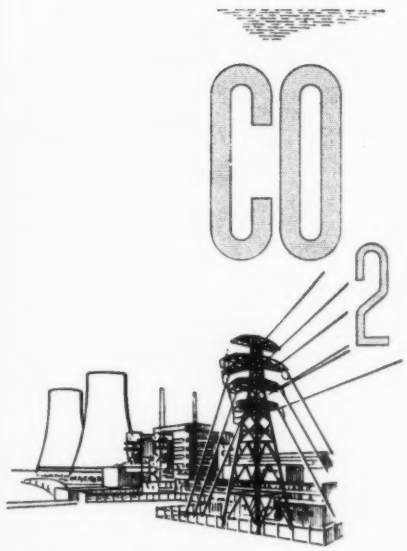
Nuclear Power

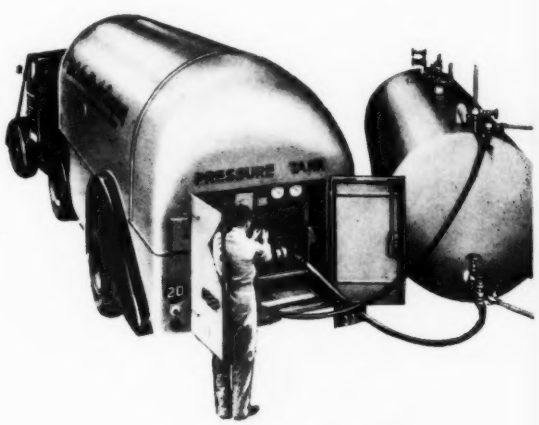
THE JOURNAL OF BRITISH NUCLEAR ENGINEERING

Carbon Dioxide in bulk



The standard system of bulk transport, storage and supply of Carbon Dioxide introduced by The Carbon Dioxide Company is suitable for all nuclear power stations using this gas as the reactor coolant/heat-exchange medium.

Already proved in use at Calder Hall and in many other industrial installations, it is the most efficient means yet developed for dealing both with the large quantities required for charging and with the smaller " make-up " feed. Transfer of the liquid carbon dioxide from tank wagon to storage is readily effected without interruption of normal operation.



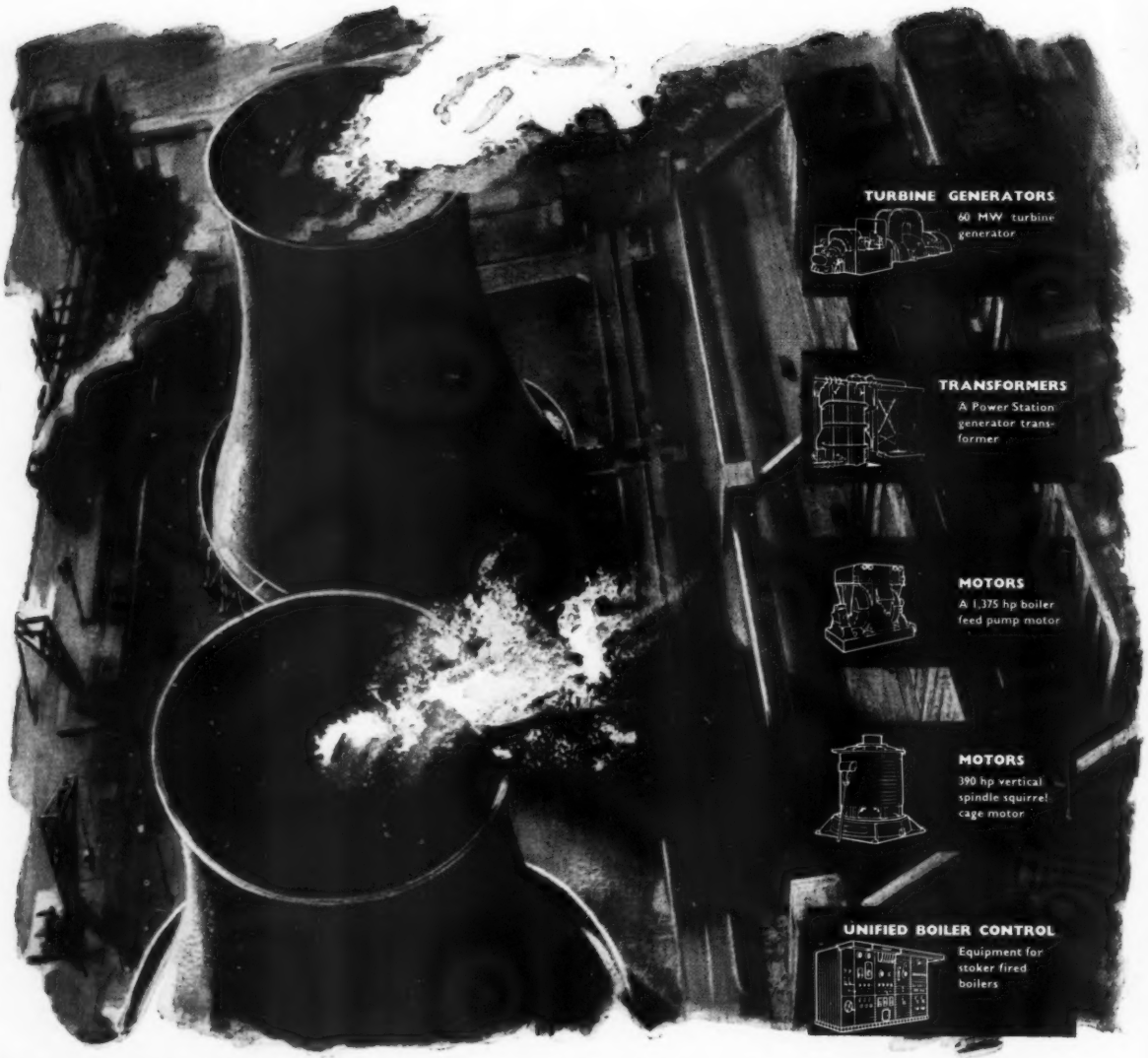
THE CARBON DIOXIDE COMPANY

A Division of The Distillers Company Limited

Devonshire House, Mayfair Place, London, W1

and works throughout the British Isles

March 1957 Volume 2 Number 11 3s 6d



TURBINE GENERATORS
60 MW turbine generator

TRANSFORMERS
A Power Station generator transformer

MOTORS
A 1,375 hp boiler feed pump motor

MOTORS
390 hp vertical spindle squirrel cage motor

UNIFIED BOILER CONTROL
Equipment for stoker fired boilers

SWITCHGEAR
3.3 kV, 150 MVA Air-break switchgear

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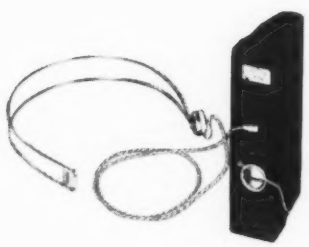
HEALTH INSTRUMENTATION

BY **PHILIPS**

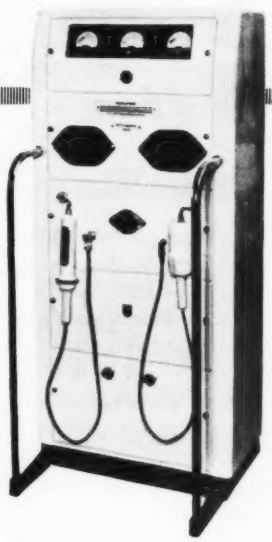
The units illustrated here are selected from Philips range of monitoring equipment designed to safeguard the health of workers in atomic factories and research establishments. Full details will gladly be sent on request.

Philips, with their many years' experience in the field of radiation measurement, are best qualified to advise on all health instrumentation problems.



Pocket Battery Monitor type PW 4010. Sensitive to gamma rays, high energy beta radiation and X-rays, with ranges for high and low sensitivity. Low intensities also audibly detectable by earphones. Ideal for intensity measurements in laboratories, checking radio-active sources or tracers, etc. *A product of N.V. Philips, Eindhoven, Holland.*

Contamination Meter type 1092D. Accurately measures gamma activity on clothing, benches, etc. Interchangeable power supply units : high tension battery, mains unit, or vibrator. Cold cathode valves throughout obviate need for filament heating and help to reduce size, weight and maintenance. *Developed in conjunction with U.K.A.E.A., Harwell.*



A number of these monitors have been supplied to Calder Hall

Hand and Clothing Monitor type 1404A. Enables workers to rapidly check their hands and clothing for harmful contamination. The instrument incorporates hand units for detecting beta-gamma radiation and, below these, two frisking probes for checking the clothing for beta-gamma and alpha radiation. Special care has been taken in design to ensure ease of cleaning and quick replacement of contaminated parts. *Developed in conjunction with U.K.A.E.A., Harwell.*

Write or telephone for full details of the complete Philips range of health monitoring equipment.

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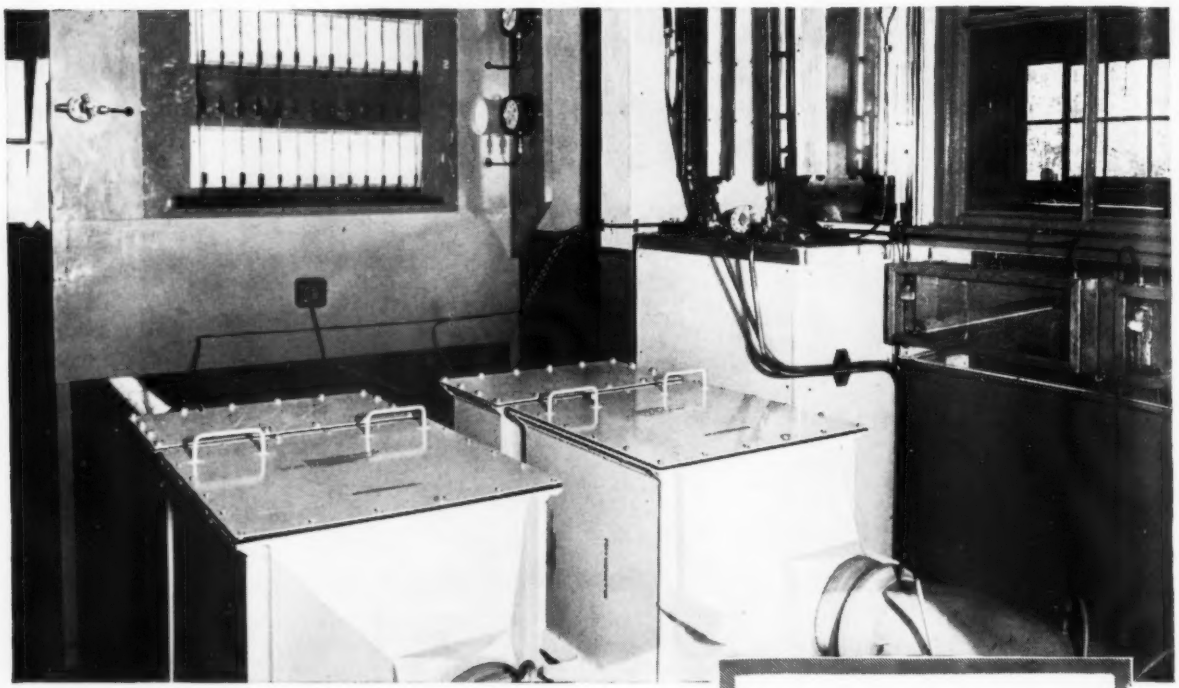
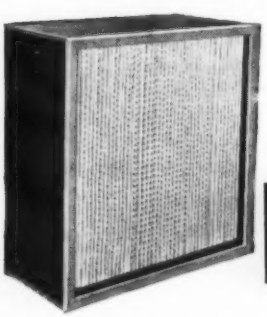
VOKES 'Absolute' air filters are individually tested



A new range of Vokes filters has been developed to ensure efficient filtration where radioactive dust (such as in nuclear energy installations) or dustborne bacteria could be really dangerous. In these cases, even submicron particles of dust can have serious results, and it is to arrest these minute particles that Vokes now offer their 'Absolute' Filters.

To ensure complete dependability, *every* Vokes 'Absolute' Filter is tested by the 'methylene blue' method★ before dispatch; any unit not registering *at least* 99.95% efficiency is automatically rejected. In this way Vokes maintain their claim of 'absolute' air filtration in those cases where serious trouble might result because of the nature of the dust.



★

How Vokes Filters are individually tested

The test—known as the 'methylene blue penetration' test—consists of a comparison of dye stains between the inlet and outlet sides of the filter. A 1% solution of methylene blue dye in water is passed through an atomiser. In evaporating, the water droplets leave dye particles of a known size in the air-stream. By number, 90% of these particles are below 0.5 micron in size, while 50% of them measure less than 0.05 micron. These are the dangerous particles stopped by the Vokes 'Absolute' Air Filters—to your plant's benefit. The box-type canister shown in the photograph was tested at 200 c.f.m. and with a water gauge drop of no more than 1.25 in. the dye penetration was only 0.003%, giving a test efficiency of 99.997%.

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WINDOW MATERIAL	mica
BACKGROUND COUNT	10 counts per minute in standard lead castles
QUENCHING GAS	Halogen
ELECTRICAL LIFE	Exceeds 10^{10} counts

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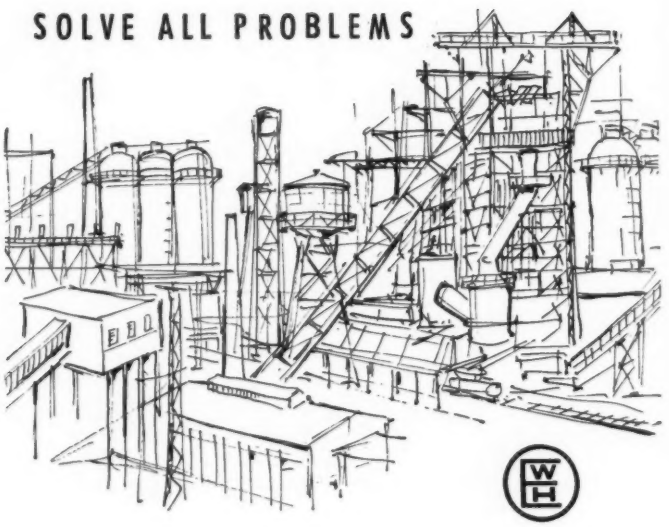

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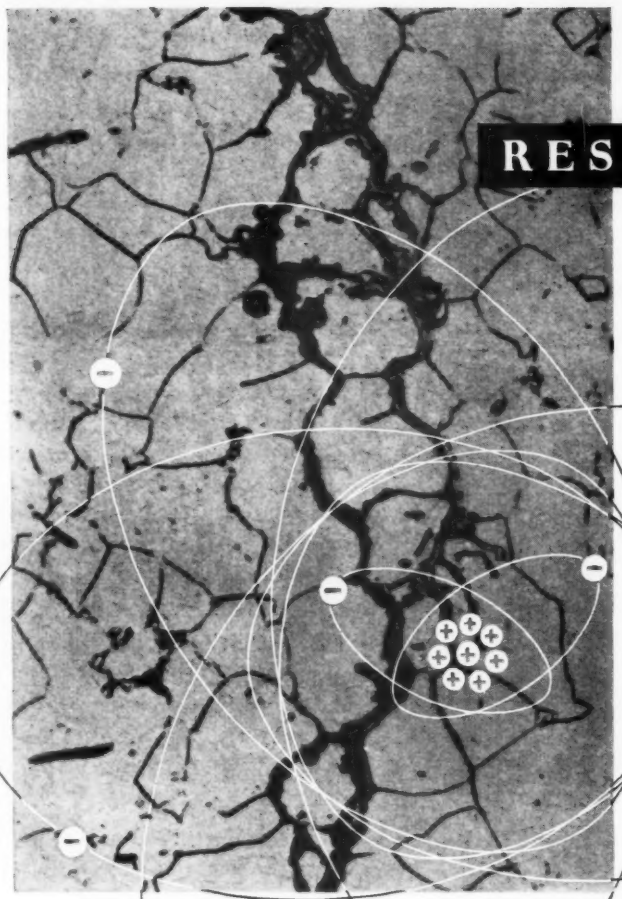

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to be built by the
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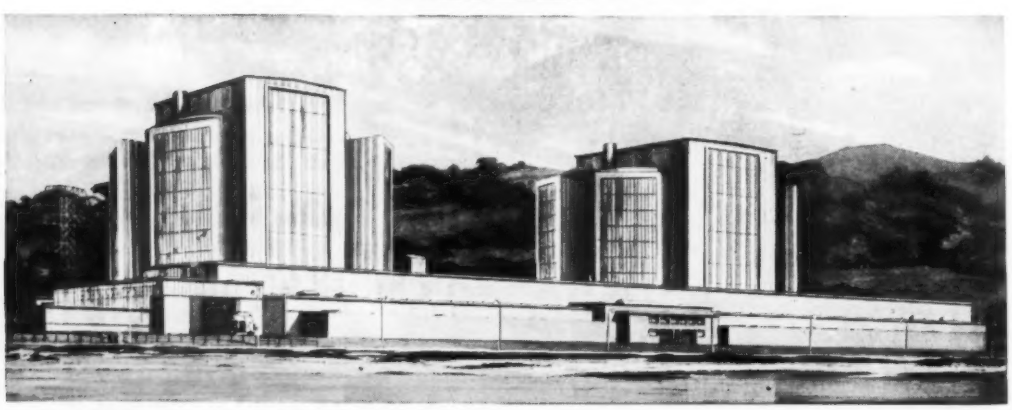

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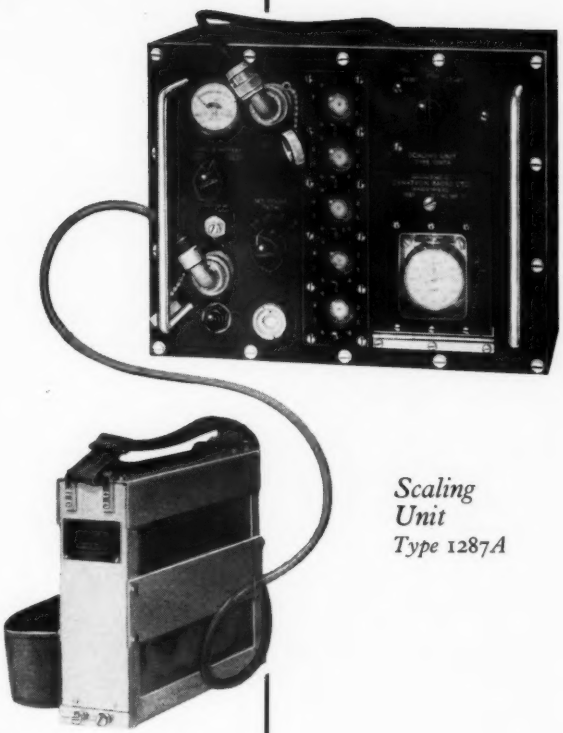
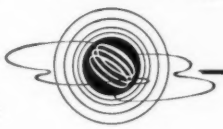
PORTABLE TRANSISTOR SCALING UNIT

The transistor-operated Scaling Unit type 1287A is a completely portable five-decade scaler, designed for arduous use in the field or any situation where essential requirements are compactness and independence of mains supply. The Scaler provides a stabilized voltage suitable for the Halogen quenched range of Geiger Muller Tubes. An appropriate G.M. tube from this range completes an equipment which is suitable for the detection and measurement of radio activity in geological surveys, mining and many other applications.

Pulses from the Geiger Muller tube are fed to a five-decade scaling circuit of adequate sensitivity and resolving time for G.M. counting. The circuit comprises five cold cathode 'Dekatron' Tubes (CV2271) driven by germanium junction transistors, enabling a total of 99,999 counts to be registered. A robust built-in stopwatch provides automatic timing, and two methods of counting can be performed.



Scaling Unit Type 1287A



SPECIFICATION:

Pulse input:	Negative
Sensitivity:	300$\mu\mu$ coulombs
Resolving time:	300μ secs.
G.M. supply:	350v $\pm$5% to 435v $\pm$5%
Auto-Count totals:	10^2, 10^3, 10^4, 10^5
Stopwatch:	1 rev.—60 secs. 1/5 sec. calibrations
Battery consumption:	0·6A nominal
Battery:	4·8v nom. 7A/H
Battery duty:	at least 10 hrs. operation from each discharge cycle

CONTROLS:

Battery On/Off Switch
Set Count-Total Switch
Count Start/Stop/Reset Switch

DIMENSIONS:

Scaling Unit: Front Panel 11 13/16" x 9 1/4" (30 cm x 23·5 cm). Depth overall handles 9 3/8" (24·5 cm). Weight 22 lb. (10 kg). Battery Case: 9 3/4" x 7 1/2" x 2 3/4" (24·75 cm x 19 cm x 7 cm). Weight including battery 8 lb. (3·6 kg).

Write for further details of this and other instruments in the Dynatron range.

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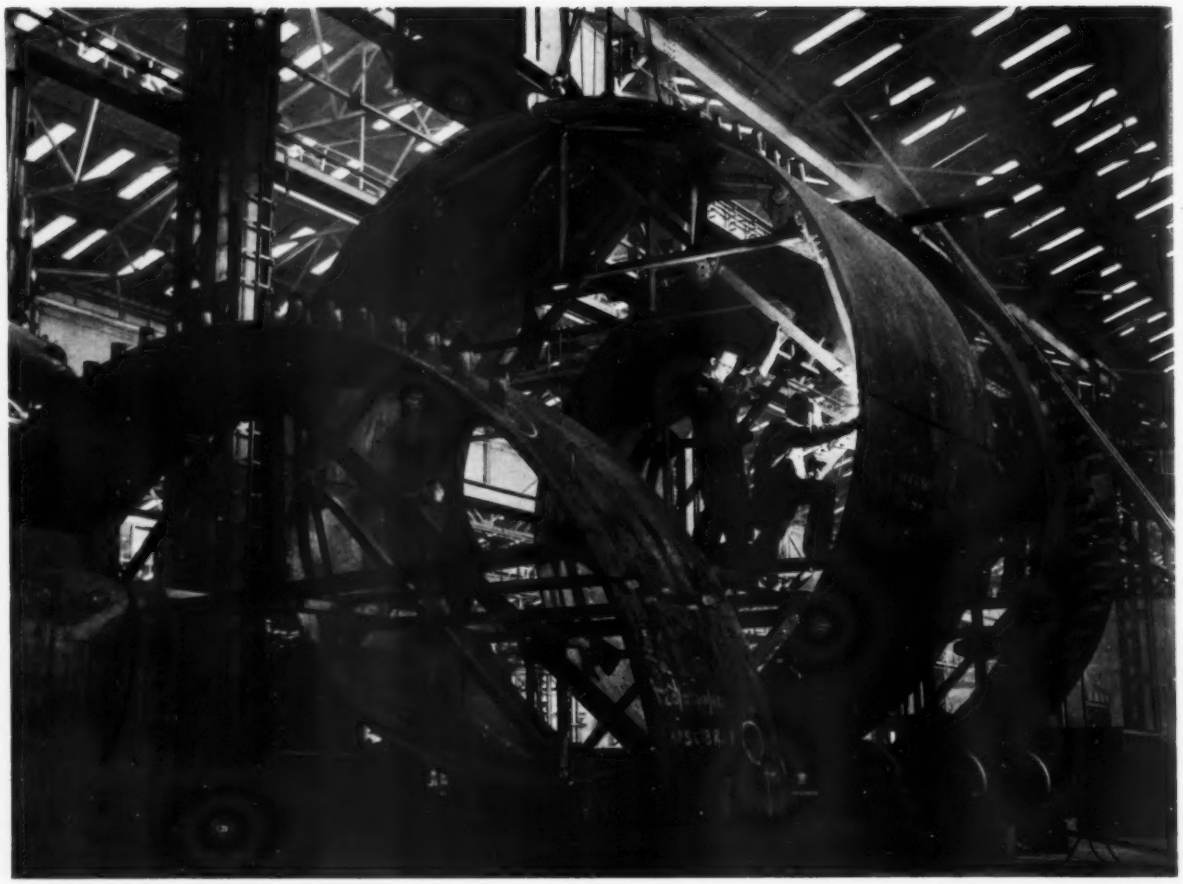

Manufacture of shell sections for the steam-raising towers of Calder Hall Atomic Power Station. [Courtesy of Babcock & Wilcox Ltd.]

Steam-raising at Calder Hall

The steam-raising plant at Calder Hall, designed and built by Babcock & Wilcox Ltd., consists of 16 welded steel towers, each 80 feet high, 17 feet in diameter and containing over ten miles of complex steel tubing. On the tubes of each tower are welded 11,000,000 fins of aerofoil section to provide the maximum surface for heat exchange with minimum resistance to the flow of gas.

In this plant carbon dioxide gas, raised to a high temperature in the nuclear reactor, is circulated under pressure over the finned steel tubes, transforming the water in the tubes into superheated steam.

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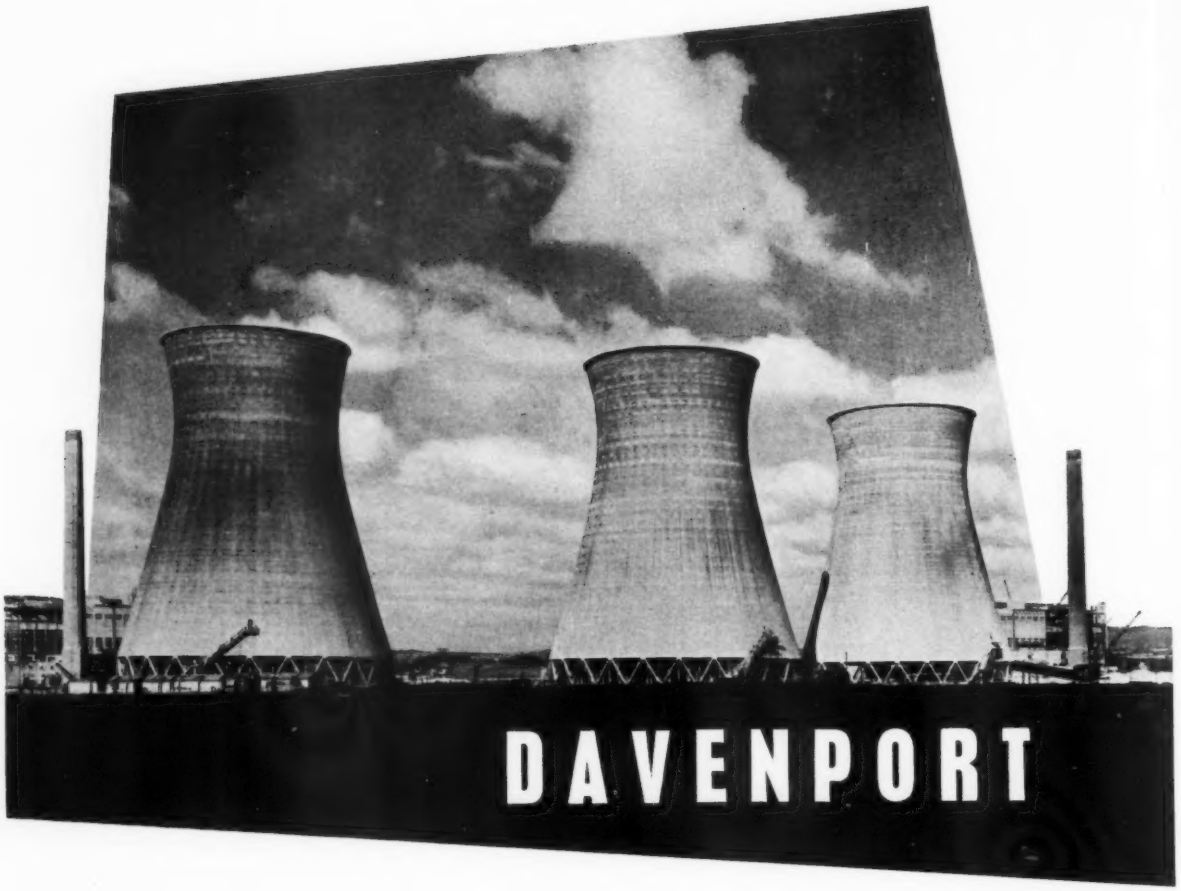

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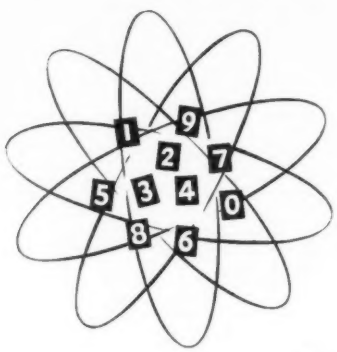
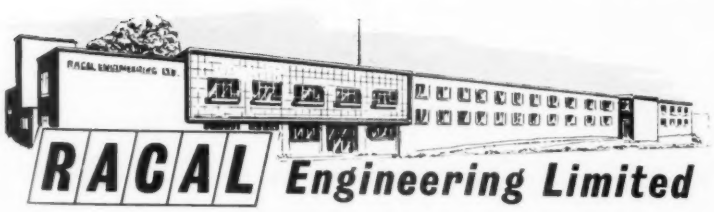


Digits in the nuclear pie

Digital counting techniques, developed in Britain by Racal, can answer many measurement and control problems in nucleonics, from high-speed precision timing and tachometry to pulse counting and delay generation. Alongside complete equipments for standard application ranges, Racal offer fourteen individual types of plug-in units (decade dividers, scalers, totalisers, triggers, gate control units, pulse invertors and cathode followers) which by their easy "permutation" enable special-purpose equipment to be built-up quickly, easily adapted and serviced. The economics are impressive, too.



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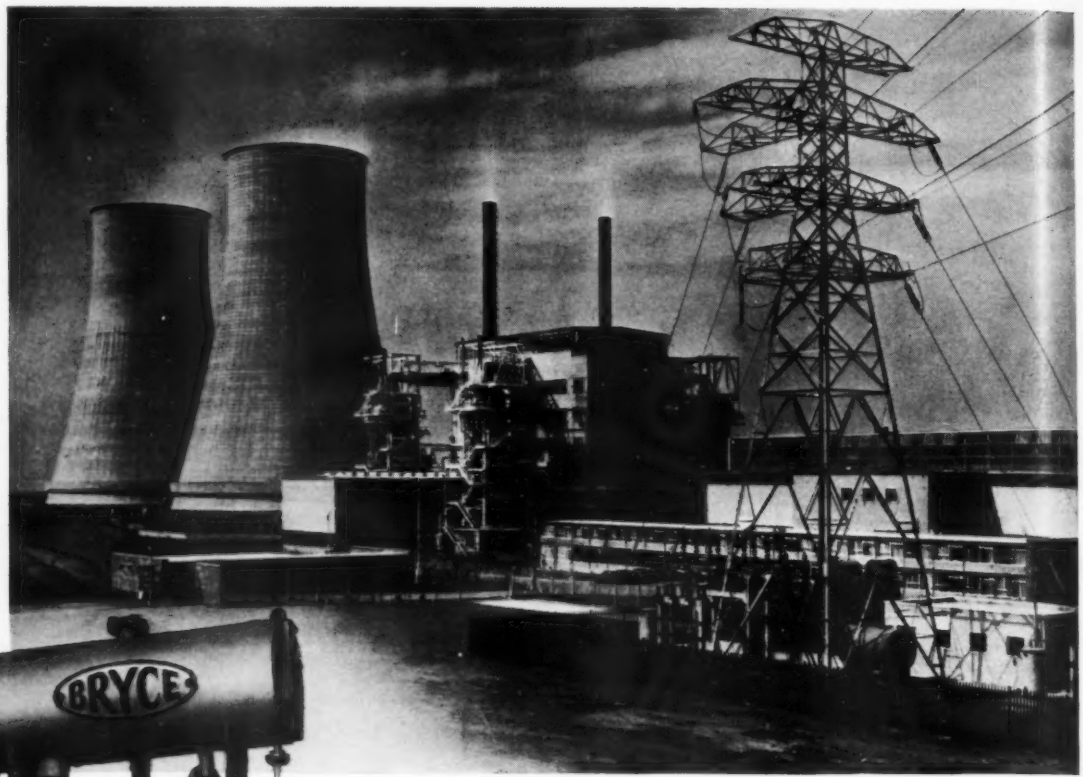

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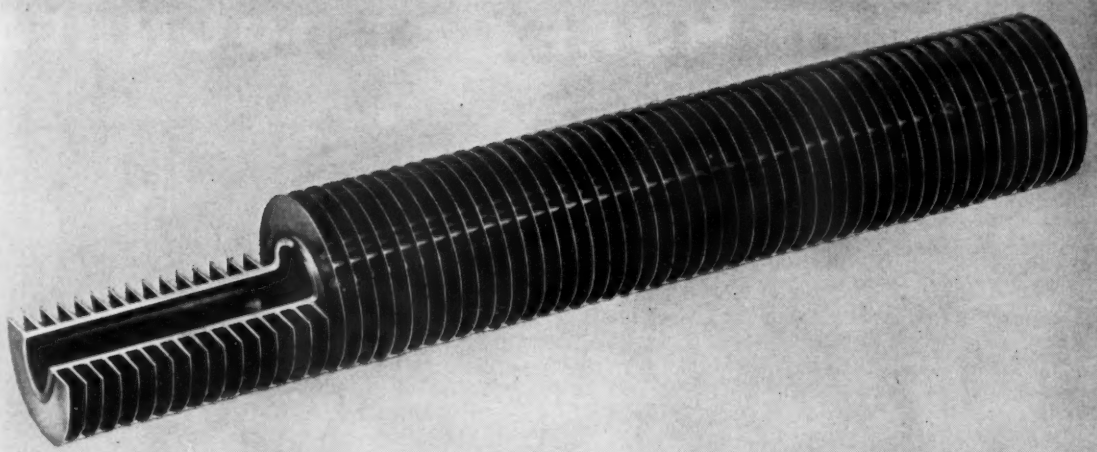

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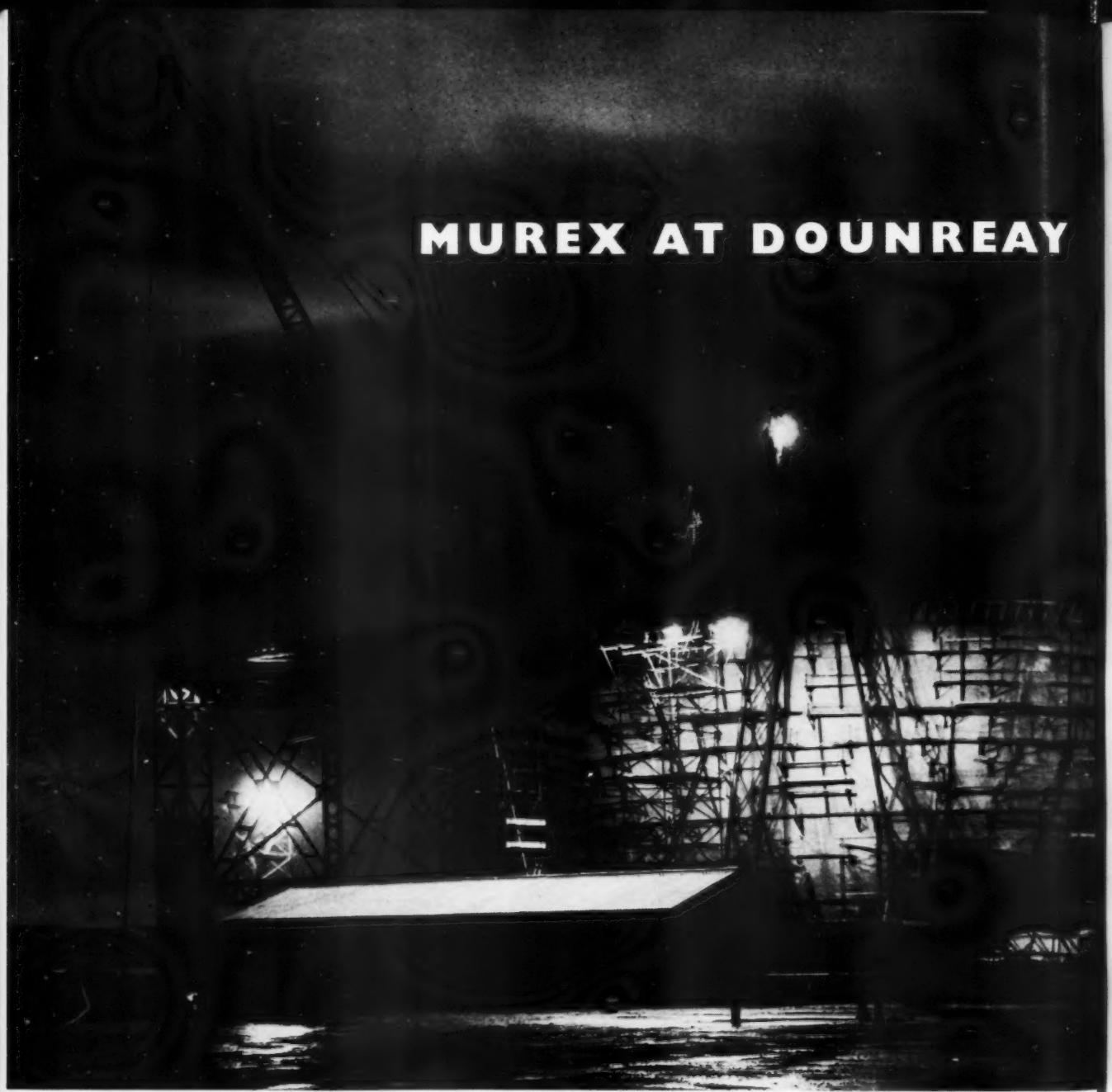

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Murex "Fortrex 35" electrodes are being exclusively used by The Motherwell Bridge & Engineering Co. Ltd., Motherwell, for all the hand welding on the huge sphere at the new Dounreay Atomic Energy Plant. This sphere is unique in design and is built to the exacting requirements of the U.K. Atomic Energy Authority. For such applications only the best electrodes can be used. Murex electrodes are at your service.

Other contractors at Dounreay using Murex electrodes include Alex. Findlay Ltd., Matthew Hall & Co. Ltd., Head, Wrightson & Co. Ltd., Whatlings, Ltd. and Thos. W. Ward, Ltd.

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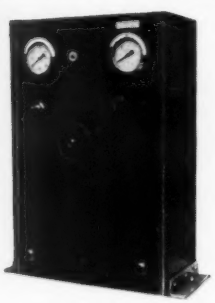

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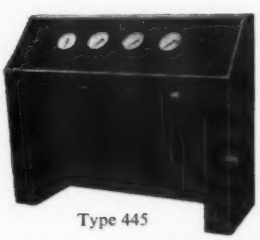

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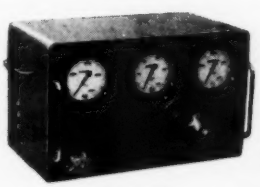

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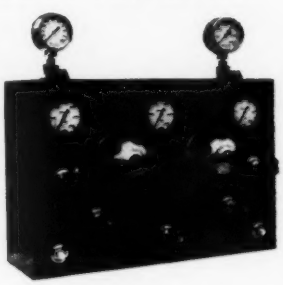

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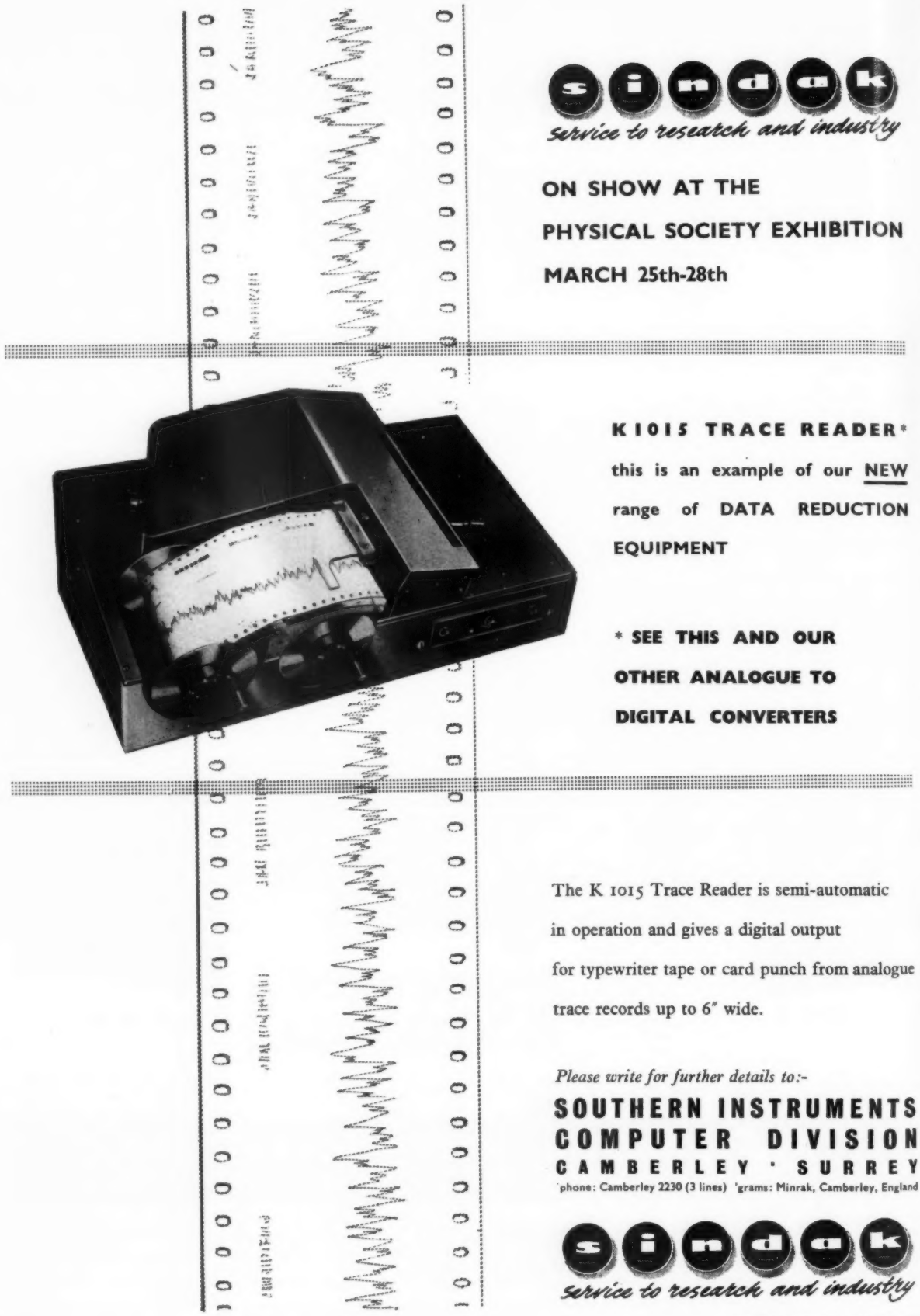

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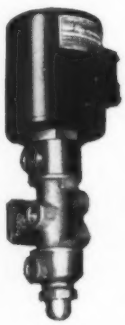

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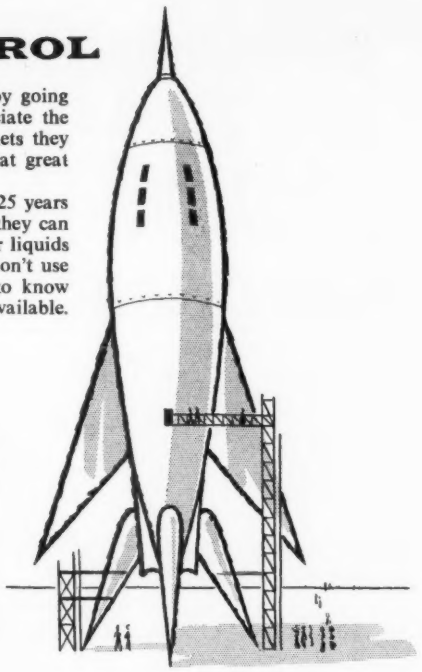

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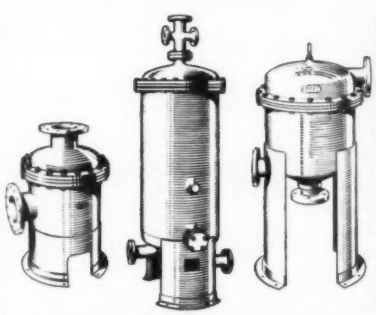

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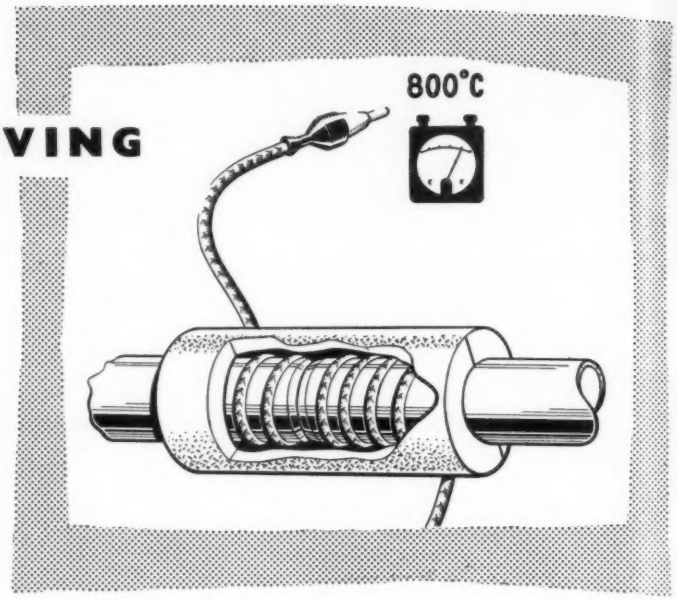

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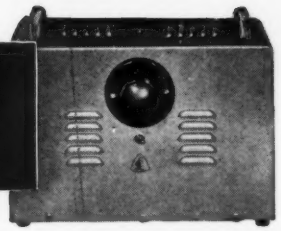

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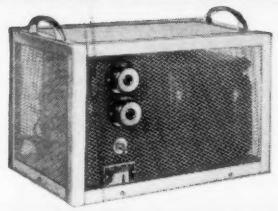
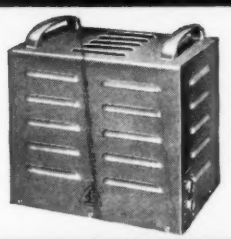
For complete data request our 20-Page Supplement Ref.V-549-S and its associated Special Price List, CLL Form VSP-56/16.



BAVR - 1000 & BAVR - 1000-E



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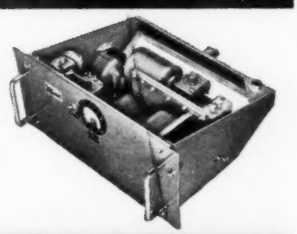

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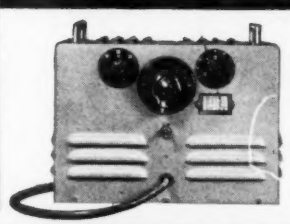
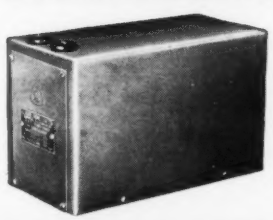


BMVR - 2750 VV & TCVR - 2750 VV



ASR - 1150 & ATC - 575

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Output Voltage Stability	±2½%	±5%	±0.15%	±0.15%	Usually ±0.5%	Usually ±0.5%
Change due to load (0-100%)	NEGLIGIBLE		±2.0%	±0.3%	NIL	NIL
Harmonics Generated	NIL	NIL	YES	YES	NIL	NIL
Response Speed	PRACTICALLY INSTANTANEOUS AVERAGING				1 V/Sec.	40V/Sec.
	2-3 CYCLES		1 CYCLE			
Power Ratings	1150VA 2300VA	575VA 1150VA	200VA 500VA 1000VA	200VA 500VA 1000VA	1600VA to 30kVA (18 models)	1600VA to 12kVA (11 models)
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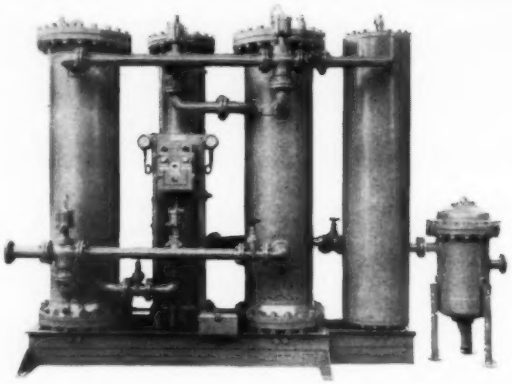

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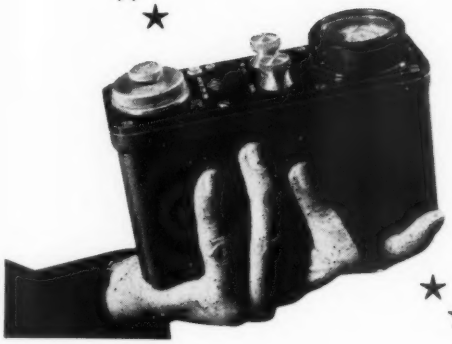

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Range 2. 0-0.5 mR/hr; time constant 1 second.
Range 3. 0-0.5 mR/hr; time constant 6 seconds.

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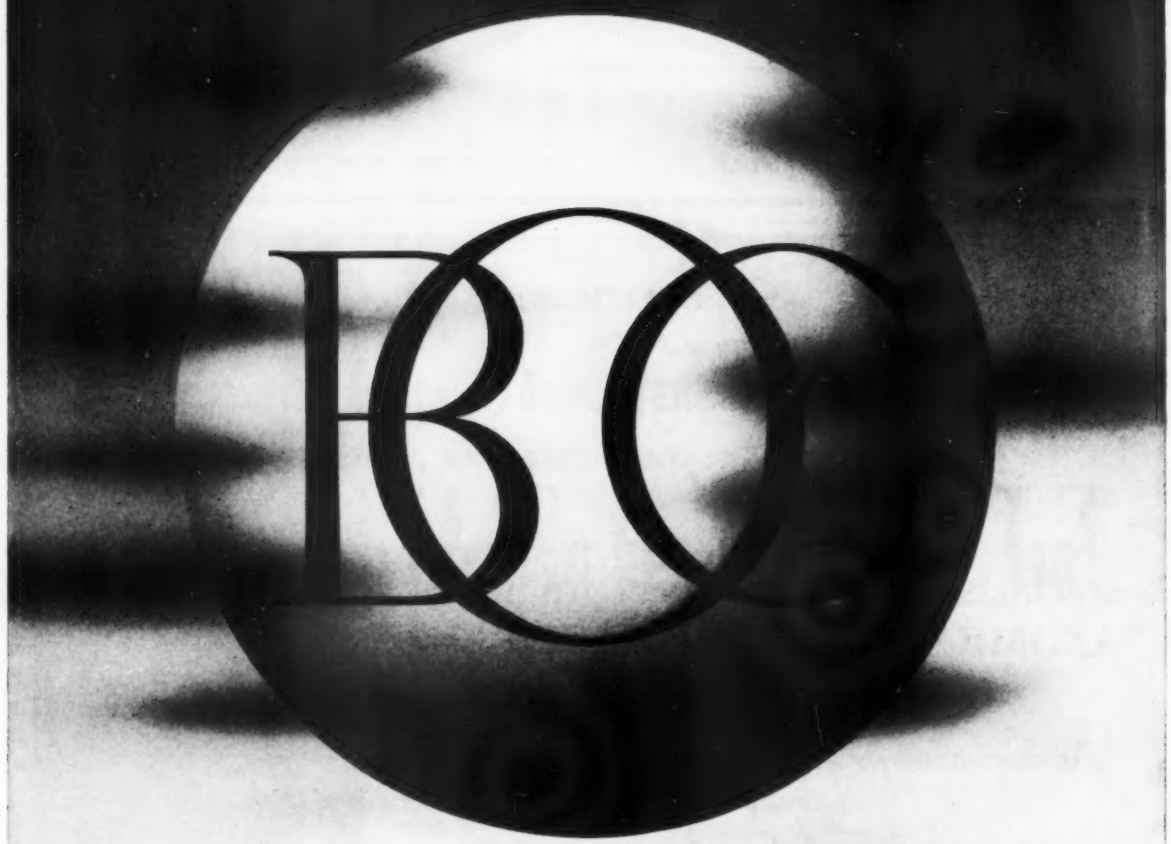

British Oxygen Gases Limited, Industrial Division, Bridgewater House, St. James's, London, S.W.1.

March 1957

Volume 2

Number 11

HERMES, the new isotope separator at Harwell, seen from the control desk (see Worldview)

Nuclear Power

The journal of British nuclear engineering

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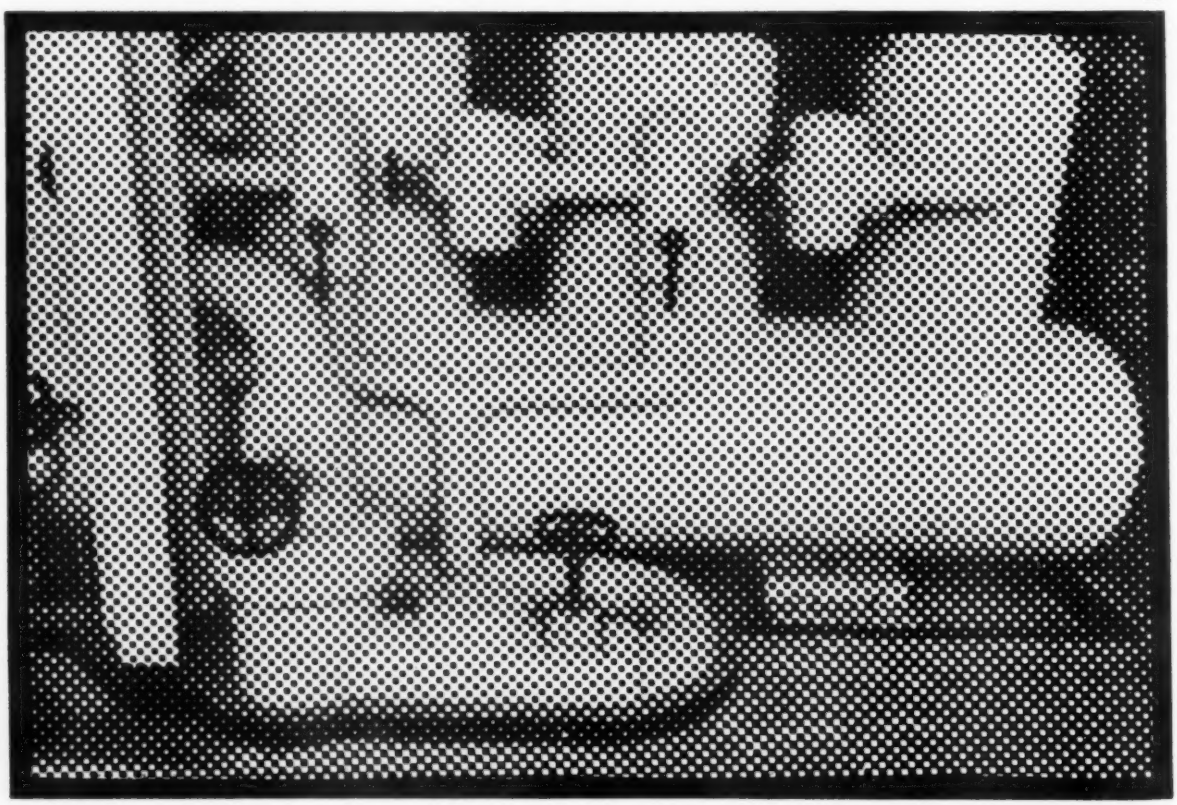

Nuclear Power
MARCH 1957 VOLUME 2 NUMBER 11

Reactor vacuum

NOW THAT SOME of the excitement and mutual admiration of Calder Hall and its embryo progeny have to some extent moderated, it might be well to consider just where we stand today in the world picture of atomic energy. That considerable achievement in Cumberland represents a break-through on a very narrow front, carried out by concentrating overwhelming forces in a spearhead attack. It succeeded brilliantly but has left something of a vacuum in the reactor world. Obviously, the big graphite reactor is here to stay and will play the leading part in our power economy for at least ten or twenty years. Certainly, there is room for improvement but this will take the form of normal engineering development rather than that of revolutionary discovery. In the said power economy however, there is scope, indeed necessity, for other parts and so far there are few signs of them being filled.

The fact is, apart from the gas-cooled reactor and some notable progress on the fast-breeder, we are seriously lagging in reactor development as a whole. Despite secret conferences on reactors of all kinds, Britain has none in the small to medium power range past the drawing board stage and at the present rate of progress it will be years before we have anything practical to offer as a working proposition.

Nowhere is this unbalance more apparent than in the field of ship propulsion, and yet work on a submarine reactor has continued intermittently at Harwell for about ten years. The very much belated appointment of a senior Naval engineer to take charge of the submarine project is perhaps a sign that the Government is at last fully alive to the necessity of pressing this development forward as rapidly as possible. This, incidentally, is probably the only good that has come out of the Suez incident. It makes depressing reading however to learn almost simultaneously with Admiral Wilson's appointment that Rickover's *Nautilus* is now due for her first fuel change—after travelling the legendary distance of 20,000 leagues! It has been suggested—and it is quite likely—that she is fabulously expensive to run. But the *Nautilus* is the very first of her kind and the sheer economics are not so important as the demonstration of feasibility and reliability which she has now so amply performed. Much the same situation obtains in the sphere of land-based or surface ship reactors: we simply have nothing within sight of being operational until 1960-61 at the very earliest.

Reasons for our general backwardness except in one auspicious sector are not far to seek. We could only do one thing at a time and Earl Mountbatten has confirmed that the big graphite reactor was given absolute priority some years ago. Now that this objective has been achieved and we are branching out in other directions, it is important to be realistic about it. Any reactor of moderate or small size must either have enriched fuel or heavy water. What the former situation is, is anyone's guess. There is probably quite a considerable stockpile, but so far the AEA have refused to give any firm assurances as to deliveries and prices of enriched uranium for civil reactors. Some declaration on these lines, similar to President Eisenhower's famous offers, would give the whole industry a tremendous fillip. Of heavy water, we have none, and since the New Zealand fiasco any hopes of our ever making our own seem to have been abandoned. Whether enrichment or heavy water is the answer is really beside the point in this context, for we have neither. And we shall have no small reactors, except perhaps for military purposes, until we provide one or the other for peaceful uses.

There is however already evident a new trend in British industry. Some far-seeing firms are anxious to get into and play a part in primary nuclear energy as soon as possible and are not content just to make components for some AEA or CEA plant. Some of these are big, many small, but even the largest obviously find it impossible to 'go it alone'—the existence of the big groups or 'consortia' show this. What then is to be done? Wait until the AEA has built a prototype and then obtain permission to develop it? That is one way—if you can afford to wait.

Another way is that already adopted by two British firms—go to America and buy the know how. Deplorable as this may be from a purely nationalistic point of view, it shows business sense. Building small and medium water-cooled reactors here—even if foreign-designed—will provide invaluable manufacturing experience, so that when we have comparable indigenous designs these firms will be particularly well placed to make them. It is also incidentally good business for the United States because few countries in the sterling area have dollars to spare for buying direct.

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information sheet

REACTOR PERIOD METER

Types 1389B 1513B

The EKCO reactor period meter is connected to a neutron sensitive ionisation chamber located near the reactor. The input current, which is then displayed on a 5″ panel meter, is representative of the reactor power level. The second 5″ panel meter shows the rate of change of input current and is calibrated in seconds to indicate the time taken for the neutron flux to increase or decrease by a factor of two. A positive reading indicates an increase and a negative reading corresponds to a decrease while the intermediate 'infinity' reading represents a steady flux with no change.

The instrument incorporates a D.C. amplifier which is designed to measure and indicate on a logarithmic scale very small direct currents over a range of seven decades. This is followed by a differentiating amplifier which measures the rate of change, this being indicated as time taken for the input current to change by a factor of two. Provision is made for giving warning when an adjustable predetermined rate of change is exceeded.

Trip facilities on both positive and negative doubling times provide for automatic operation of the reactor warning and safety circuits. 'Fail-safe' precautions ensure that failure of a major component trips the alarm facility. The equipment comprises two units—the Main Unit and the Head Amplifier. Two different versions give alternative facilities as detailed in the Specification.

SPECIFICATION

	Type 1389B	Type 1513B
Input Current (Accuracy ±10%)	5×10^{-12} to 5×10^{-5} amps	$5 \times -^{12}$ to 5×10^{-5} amps
Doubling Time (Accuracy ±5%)	—80/infinity/+20 secs.	—20/infinity/+5 secs.
Trip-Setting Range	Between 60 and 20 secs., positive and negative	Between 15 and 5 secs., positive and negative

Controls etc: No controls are located on the front panel, pre-set and calibration controls being housed in an inset panel visible through a window in the covering door. Two telephone-type jacks are provided to permit checking and calibration of both the logarithmic D.C. amplifier and the period meter. Relay contacts are connected to plugs at the rear of the instrument for incorporation in warning and trip circuits. A lamp on the front panel is extinguished when the trip circuit operates. Sockets are provided for the connection of external meters and/or recorders if required.

Power supply: H.T. supplies are stabilised and incorporate thermal delay switching which protects the valves by delaying the application of H.T. until the cathodes reach operating temperature. The equipment operates from A.C. mains of 110–120 Volts or 200–250 Volts, 50/60 c/s.

Construction: The main unit is built on a standard rack-mounting panel, size 19″ x 10½″ (48.3 x 26.7 cm.) and is approximately 14″ (35.5 cm.) deep. The head amplifier contains the input valve and is a sealed casting which can be mounted either within the main unit or adjacent to the ionisation chamber.

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UNITED KINGDOM

Winfrith to go ahead

The site for the AERE's new research station at Winfrith Heath, Dorset, was finally approved last month by Mr Henry Brooke, Minister of Housing and Local Government, after a public inquiry had been held. In announcing his decision, the Minister said that objections had been of three main types—the new research centre would impair local water supplies, it would spoil the fine landscape, it would lead to the urbanization of the countryside. He was satisfied that the establishment's water supplies could be met without prejudice to those of other consumers. Effluent disposal would be investigated further in greater detail but he saw no reason to believe that local fisheries would be affected. He did not consider that the project need result in the industrialization and urbanization of the countryside and the county council would see that it did not. It was inevitable, the Minister's statement went on, that some of the present qualities of the area would be affected, but having weighed these considerations against the national importance of the project, the local support for it, the county council's provisional approval, and the careful control which will be exercised, he had come to the conclusion that it would be wrong to withhold his consent.

Navy name atom chief

Britain's drive to develop nuclear power for ship propulsion took a tangible step forward last month with the appointment of Rear-Admiral G. A. M. Wilson as Rear-Admiral Nuclear Propulsion and Deputy Chief Engineer (Nuclear Propulsion) at the Admiralty. Making this announcement, an Admiralty statement said it believed in the vital importance, both to the Royal and Merchant navies, of the early development of nuclear propulsion for ships. Admiral Wilson, continued the statement, will act as the focus within the Admiralty of the operational and material aspects of nuclear propulsion, and will keep in touch with developments by the Atomic Energy Authority and by industry in the application to ships of this revolutionary form of power. He will also be the link in these matters between the Admiralty and other Government Departments and between Commonwealth navies and foreign navies as appropriate. Admiral Wilson will also direct the work of the Navy section at Harwell which has, for some time, been working on propulsion problems under Captain Harrison-Smith.

Some progress on the submarine project was reported in the Commons on January 30 when the Civil Lord of the Admiralty, Mr T. G. D. Galbraith, announced that the detailed design of a land-based prototype propulsion unit was well advanced and some orders for parts had been placed. A 'basically similar' power plant would later be built for sea trials in a submarine.

Nuclear propulsion would by now have been much farther ahead had it not been for a decision taken some years ago that land-based reactors for electricity production must have priority. This was stated by Admiral of the Fleet Earl Mountbatten in a speech to the Navy League in London on January 18. Vice-Admiral Sir Frank Mason, Engineer-in-Chief of the Fleet, also referred to the submarine recently when he declared it 'almost wholly an engineering problem and one that can only be solved by the engineering industry.'

Alco reactors for Britain

Another British firm have concluded an agreement with an American company for the manufacture of nuclear reactors. Speaking in London on January 29, Mr Ambrose Congreve, chairman of Humphreys & Glasgow Ltd, the well-known gas, process and mechanical handling engineers, announced that his company had concluded an agreement with Alco Products Inc of Schenectady, NY, under which they would have full marketing rights outside the American continent for the reactor developed by Alco. The reactor is a pressurized water type which was originally developed by the US AEC for the *USS Nautilus*. Modified, it is now the basis for the APPR-1 2 MW reactor which is due for completion at Fort Belvoir, Washington, in a few weeks. Humphreys & Glasgow are now, continued Mr. Congreve, ready to accept orders for this type of plant with outputs of from 2 to 20 MW. Although concentrating on exports, he would very much like to book his first plant in the UK or in Eire.

Speaking as Vice-President (Engineering), Alco Products, Rear-Admiral Wilson D. Leggett, Chief of the Bureau of Ships, 1953-5 said the APPR at Fort Belvoir would provide valuable 'debugging' experience and would ensure that the export reactor was fully operational. He said that at first certain special items such as control rod actuators would be supplied by Alco, but as time went on the British company would supply the entire plant with the exception of the fuel elements which would come from the AEC.

Reasons for choosing the Alco PWR were elaborated by Brigadier W. B. Sallitt, Humphreys & Glasgow's Nuclear Engineering Division Head. The company believed that Britain must export —and export quickly. For this reason they had gone to Alco because: 1. The range of outputs—up to say 25MW—was just right for exports. 2. The PWR system really works—it has run for two years without refuelling in the *Nautilus*. 3. It is simple. The design is conservative and uses only common materials. 4. It is safe. The first PWR went into a submarine, the second into a garrison town just outside Washington. 5. It is efficient and economical. Mr Congreve mentioned a capital cost of about £2m for a 10MW station with a unit cost of about 1½-2d per unit. This would compare favourably with conventional power in many localities. 6. Most of the plant would be built in the UK so the dollar payment would be quite small. 7. Finally, Brigadier Sallitt believed that Alco possess a wealth of 'know-how' which does not exist on any other reactor of comparable size—it was at least three years ahead of its competitors. A full description of the H & G-Alco reactor appears elsewhere in this issue.

About two-thirds of the engineering requirements for the first reactors will be built in Britain and a large proportion of this will be manufactured by the 115-year-old firm of Daniel Adamson & Co Ltd at their Dukinfield, Cheshire, works. Announcing this, Daniel Adamson chairman Mr R. W. Parkyn said 'we are pleased to announce that our eleven years' technical association with Alco Products Inc (formerly American Locomotive Company Inc) under which we manufacture Alco designed heat-exchanger equipment for the British Commonwealth and elsewhere has been further strengthened. We are now the manufacturing licensees for the nuclear equipment required for the Alco range of 2 to 20 MW capacity plants.' This would chiefly consist of: shield tanks, steam generators, pressurizers, spent fuel pit and fuel vault equipment, blowdown tanks, exchangers etc.

Mr Parkyn is a great-grandson of the firm's founder, Daniel Adamson, who was apprenticed to Robert Stephenson the railway pioneer. The company at present employs about 1,200.

Hunterston decision awaited

The public inquiry into the proposed choice of Hunterston as the site for the South of Scotland Electricity Board's £37m nuclear power station, for which the GEC Simon-Carves Atomic Group have received a contract, was concluded last month. Mr C. H. Johnston, advocate for the principal objectors, attacked the methods of the Board and maintained

that insufficient consideration had been given to alternative sites. He also said that the Board's attitude had been that agriculture and amenity must take second place to electricity generation. He advocated a year's delay before building began.

Counsel for the Board, Mr A. Thomson, QC, denied that other sites acceptable to the Reactor Location Panel had not been given favourable consideration. He agreed it was important to keep off agricultural land wherever possible, but said this factor must be considered in relation to the whole project. He maintained that if construction were not started by the middle of this year it might never be started.

The Commissioner, Sir Randall Philip, QC, is now preparing his report which will shortly be presented to the Secretary of State for Scotland, the Rt. Hon. John S. Maclay.

Power station for Wales?

A deputation from the Welsh Labour Group of Members of Parliament met the deputy chairmen of the CEA, Sir Henry Self and Sir Josiah Eccles, and other officers in London on January 31. Their purpose was to urge the Authority to consider Welsh claims in planning the nuclear power station programme. After a full discussion the MPs were given to understand that there were good prospects of their claims being satisfied.

Later, the CEA met representatives from Cardiganshire County Council, and after discussion the Authority agreed to include the county's coastal strip in their survey for sites.

Stage II reactors for Scotland?

The North of Scotland Hydro Electric Board is currently boring in the Crimond-Rattray area of Aberdeenshire. This follows earlier work in the area when surveyors inspected the site with a view to ultimate use for atomic energy generation. The Board has not indicated its intention to launch a nuclear project in the North-east, although the preliminary moves are now being made with such a possibility in mind. Existing power stations in this part of Scotland will need to be renewed in due course and a decision would then be required between coal-fired and nuclear stations.

Since current siting policy suggests that future coal-fired stations will be located on coalfields to eliminate or minimize transport costs, it is a reasonable assumption that the Board will eventually initiate a nuclear project. The work now being done confirms this viewpoint and suggests that the hydro authorities are looking ahead and have meantime regarded Crimond as having the essential requirements for the purpose in mind.

Glove boxes discussed

A symposium on glove box design and operation was held at Harwell from February 19 to 21, attended by university research workers, representatives from industry and delegates from overseas atomic energy authorities. Papers were presented on the general design of both shielded and unshielded boxes, their installation and maintenance and their application to chemical, metallurgical and large-scale operations. During the conference, delegates toured typical installations in the chemical and metallurgical laboratories at Harwell.

Separating Pu isotopes

A new electromagnetic separator for heavy isotopes named HERMES (Heavy Element and Radioactive Element Separation) went into operation at the AERE, Harwell, last month. Designed mainly for the obtaining of milligram quantities of the higher isotopes of plutonium, the machine is entirely inside a sealed room, access being allowed only to personnel in frog suits. A picture of HERMES appears on the contents page.

Experts confer on insurance

International cooperation in the insurance of atomic energy plants was discussed at a conference held in London last month at which representatives from twelve European nations took part. A statement issued afterwards by the British Insurance Association declared that British insurance interests have always considered that the large sums for which cover for material damage and third party risks will be required will certainly be greater than can prudently be handled in any one national market. Consequently, consideration has had to be given to methods of collaboration between the various insurance and reinsurance markets of the world.

No definite conclusions were reached but it was felt that the conference fulfilled a useful purpose in enabling the various countries to elaborate their individual difficulties. Hope was expressed that ultimately a method would be found of handling the business in a reasonably uniform way so as to make possible the fullest international cooperation.

SOVIET UNION

IAEA statute ratified

One of the first nations to do so, the Soviet Union has ratified the statute of the International Atomic Energy Agency. Together with 80 other nations, the USSR signed the statute in New York last October. This was subsequently endorsed by the USSR Council of Ministers and last month it was ratified by the Praesidium of the Supreme Soviet.

Yugoslav bilateral

Following talks between Soviet and Yugoslav delegations, a protocol to the 1956 bilateral was signed in Moscow on February 9. The protocol envisages further cooperation between Soviet and Yugoslav organizations in the field of nuclear physics research and the peaceful uses of atomic energy.

Nuclear planner dies

Vyacheslav Malyshev, Soviet Minister of Machine Building, died in Moscow last month at the age of 55. Besides his work in state planning—he was chairman of Costekhnika, the body which introduces advanced techniques into the state economy—it is widely believed that he was the organizer of Russia's atomic production programme. It is of interest to note that Mr. Malyshev died of leukemia, a disease which can be caused by radiation exposure.

Progress on icebreaker

Some details of the Soviet icebreaker were released last month. Named the *Lenin*, the ship will displace 16,000 tons and will have an overall length of 440 ft and a beam of 88 ft. It is designed to cut through ice up to 6 ft thick. Control is stated to be automatic and the fuel consumption quoted as not exceeding a few grams a day. A large part of the hull, welded from a special type of highly durable steel, has already been assembled from prefabricated sections, some of which weigh as much as 75 tons.

UNITED STATES

20,000 leagues under the sea

As the *USS Nautilus* completed its 60,000th mile and so equalled the 20,000 league record of its fictional forbear, the Navy announced in Washington on February 1 that three more nuclear powered submarines are to be built. The Ingalls Shipbuilding Corporation of Pascagoula, Mass, will build two of the ships for about $41m, while the third contract went to General Dynamics Corporation of Groton, Conn, for $25.8m. Bureau of Ships Chief, Rear-Admiral A. G. Mumma said the new vessels will be of the attack type with Albacore hull and single screw.

Nautilus equalled Jules Verne's famous fantasy in an overnight underwater cruise out of New London, Conn, and, announcing this event, the Navy said the parallel between the two craft had become complete. The fictional *Nautilus* was powered by 'a secret and unknown force': the real *Nautilus* was driven by a force contained in material no larger than a golf ball—yet so powerful that it has enabled the craft to travel the en-

tire distance without refuelling. She is due for the first refuel this summer and will go into dry dock.

The Navy have not been so lucky with the liquid-metal-cooled *Seawolf*. The Submarine finally went to sea in January—months behind schedule—with, it is understood, no superheating. This was due to corrosion troubles in the superheaters experienced with the NaK coolant. The reactor itself, is said to have given no trouble. All the new submarines will be water-cooled.

New ship programme

The AEC and the Maritime Administration announced plans on January 25 for a joint long-range programme for ships. This is additional to work on the first nuclear ship, announced by President Eisenhower last October (NP November). Named as head of the joint group is Richard P. Goodwin—until recently, Director, Technical Operations Division, AEC San Francisco Operations Office. He will report to Maritime Administrator, Clarence G. Morse and AEC Director of Reactor Development, W. K. Davis. Under the joint scheme, AEC will take reactor developments to the prototype stage after which the Maritime Administrator will look after the production of the complete ship. Six design studies are at present taking place on four reactor systems and selected ones are expected to move over into the hardware phase later this year.

Later, on February 15, the US Navy announced the award of a $4m contract to General Electric for the propulsion machinery for the Navy's guided missile carrier. Last September the reactor contract for the ship went to Westinghouse and in October it was announced that Bethlehem Steel would build the ship.

The next 18 years—Libby

Output from nuclear reactors in the United States will probably amount to between 50,000 and 75,000 MW by 1975, according to Atomic Energy Commissioner Willard F. Libby, speaking in Denver, Col, on February 8. This would require several hundred reactors, and would represent "a phenomenal growth." US reactors now building or definitely planned will have an installed electrical capacity greater than 1,000 MW by 1962, he said. By 1965 an installed capacity of 3,000 or 4,000 MW seemed likely. He estimated that the rate of installation by 1975 would be 8,000 to 12,000 MW of new nuclear capacity each year.

Dr Libby reported that AEC recently made a census of US-built reactors of all types, including those now dismantled. The total number was 231, of which 94 are in the planning stage, 46 are being built, 74 are completed and in being and 17 have been dismantled. Whilst it was true that only five of the 46 reactors which are now being built are full-scale civilian power reactors, it was clear that the construction of a few hundred power reactors in the next decade or two would not be too great a task for American industry. He told the mining conference that substantial numbers of nuclear merchant ships will probably be constructed in the 1960's, when replacement of much of the present US merchant fleet will be under way.

AEC commissioner dies

The death occurred in Washington on February 8 of Dr John von Neumann, aged 53, who was a member of the AEC since 1954. Born in Budapest, he went to Princeton University in 1930 as a visiting professor in mathematics and after an appointment as research professor at the Princeton Institute for Advanced Studies, collaborated with Einstein on several projects. Dr von Neumann became an American citizen in 1937. He was an outstanding mathematician and did some important work on high-speed calculating machines and in the nuclear field. In 1946 he was awarded the Medal for Merit and the Distinguished Civilians' Service Award for his work in nuclear science. In 1954 he was appointed by President Eisenhower to serve a five year term as a member of the AEC. Last year he was awarded the Medal of Freedom.

TN talks at Berkeley

A joint US-UK conference on controlled thermonuclear reactions was held in Berkeley, Cal, from Feb 20 to 23. Dr P. C. Thonemann of Harwell headed the British delegation of eleven scientists, which included Sir George Thomson, two representatives from the AEI, Aldermaston, one from Weapons Research, Aldermaston, and six from Harwell. Nearly four hundred American scientists and thermonuclear experts attended the conference, among them Dr Arthur E. Ruark, head of the AEC TN research programme, 'Project Sherwood.' The conference took place under the 1955 bilateral which permits the exchange of classified information in certain areas. It was under the general direction of Dr Thomas H. Johnson, director of the AEC research division in Washington.

INTERNATIONAL

OEEC study groups report

The OEEC Nuclear Energy steering committee met in Paris on January 25 under the chairmanship of Prof L. Nicolaidis (Greece) to hear reports from the study groups. On chemical processing, Dr E. Pohland (Germany) said they were concentrating on a plant to handle about 50 tons of uranium a year which would be used from 1960 onwards. Complete layout and estimates are due later this month. The majority of the group favour forming an international company to carry out the work.

Dr L. Kowarski reported on proposals for experimental reactors. Outlining a programme costing about $30m a year spread over several years, he envisaged in the first place a very high flux MTR and a light-water boiling reactor. The next stage might consist of a homogeneous aqueous reactor, and a third, of studies for an LMFR, a fast breeder and other advanced reactors, particularly plutonium-fuelled.

On nuclear power stations the experts' report said they were studying reactors on which there was adequate experience —Calder type, PWR, SGR, and BWR.

Euratom agreement near

Agreement has finally been reached on the outstanding problems of the Euratom and European common market treaties between France, West Germany Italy and the Benelux countries. The drafting of the texts of the treaties will now be left to experts of the six governments, and it is hoped that they will be ready for signature in Rome late in March, although ratification is by no means merely a matter of form.

Under the Euratom agreement, all fissionable material produced for peaceful uses by the six countries will belong to Euratom agencies, but material suitable for military applications will revert to national ownership. A common research centre is to be set up for which the budget is estimated at £70m, spread over five years.

A Euratom committee of experts, consisting of M. Louis Armand, Herr Franz Etzel and Prof Francesco Giordani, visited Washington last month for talks with President Eisenhower, the State Department and AEC. As a result, the committee established that their objective of installing over the next ten years nuclear plant with a total generating capacity of 15,000MW is a feasible one. The US pledged full cooperation with Euratom, and have agreed to supply all the enriched uranium required. A joint committee of experts to be designated by the Euratom Committee and the AEC will continue to investigate the technical problems posed by the objective.

The three Euratom experts arrived in the UK on February 25 for talks with Lord Salisbury, Lord Mills, Sir Edwin Plowden and members of the AEA, and also with directors of the main companies concerned with the construction of nuclear reactors. They also visited Calder Hall.

Eight months of operation at Calder

Sir Christopher Hinton reports complete satisfaction

AS WORK PROGRESSES on the gas-cooled reactor, the more promising it looks. This was asserted by Sir Christopher Hinton in London last month, reporting on the experience gained in the operation of Calder Hall A during its first eight months of activity. Reactor No. 2 was recently brought up to full load and is now producing electricity for the grid, increasing the total generating capacity of the plant from 46 to 92 MW installed. Sir Christopher stated that the plant went into operation more smoothly and with far less trouble than is normally experienced in commissioning a conventional power station or chemical manufacturing plant. No. 1 reactor first became divergent on May 22, on August 20 steam was first used for driving the turbines, and on October 17 the Queen turned the power into the CEA grid. Since then the plant has operated for 90 per cent of the available hours, 5 per cent more than was originally predicted. It has not, however, always been at full load since it is necessary to arrange for the initial fuel charge to be properly phased in order to optimize the burnup. The running of the station is smooth and flexible, and it is possible to reduce output from full load to 5 or 10 per cent and back to 100 per cent within half an hour, a facility which is not possible with coal-fired power stations. The power is regulated by means of the control rods until the steam quality is insufficient to run the turbines, after which it is diverted to the dump condensers.

Asked whether this meant that the Calder system might be suitable for peak load stations, Sir Christopher replied that there was no technical objection, but since the capital cost of such stations was such a high proportion of the unit cost, their use for this purpose would not be economic and it was preferable to keep them on base-load generation.

The reported carbon dioxide leakage occurring at places such as valve spindle glands, is being progressively remedied by conventional engineering methods. Carbon dioxide itself does not become radioactive, but argon, present as an impurity in the commercial form of the gas, yields a radioactive isotope when irradiated with slow neutrons. A rigid specification is therefore laid down for the CO_2, keeping the argon content at less than 1 ppm by weight. The extra operating cost caused by the leakage is negligible as carbon dioxide is a relatively cheap commodity.

Generally, the fuel element performance has been better than expected, and there have been only two burst slugs during the whole of the eight months—a figure much lower than that predicted from the performance of the Windscale reactors. But the irradiation creep rate under load of the lower elements is greater than was anticipated. This effect was predicted theoretically at Harwell shortly before No. 1 reactor become divergent, and a subsequent test of the irradiated elements, for which the reactor was closed down on one occasion, has shown that the theory is, at least partially, correct. As a result, a support feature has been incorporated at the centre of the cartridges which provides lateral restraint against the channel wall. The improved element has been incorporated in No. 2 reactor, and will be used to replace the spent slugs in No. 1 at its next routine shut-down, which will take place in the near future.

The Windscale Works will be able to handle the processing of the spent fuel from all the AEA stations and from the early CEA plants, but as the programme develops additional capacity will be needed. It is intended to erect this on the Windscale site and it will probably be needed by the early 1960's. The fuel will be transported from the power stations by road and rail in massive shielding containers.

Sir Christopher agreed that there was a pronounced shortage of thick steel plate and said this must be tackled as a national problem. Prestressed concrete, as used in France, had many attractions since it could be used for a combined pressure shell and biological shield. The idea, in fact, had been investigated as far back as 1947 in a Harwell design study but because there is so much in a nuclear power plant which is experimental, it was felt wrong to introduce another uncertainty when conventional methods were available.

On the question of gas or liquid metal coolants for thermal reactors, the IG Managing Director felt that it was too early to express decided preferences. Gases would reach higher top temperatures but metals had a much better heat transfer. The choice would depend largely on the duty requirements of the plant.

Plutonium as a recycle fuel for thermal reactors has not been entirely dismissed yet, but the greatest hope for this fuel is in fast reactors. The Capenhurst gaseous diffusion plant for uranium enrichment was constantly being extended and improved and its operations had now become completely routine.

Sir Christopher Hinton was accompanied by Mr L. Rotherham, Director of Research and Development, and Mr R. V. Moore, Assistant Director (Civil Reactors).

THE SCOTTISH POWER STATION

In our article on the South of Scotland Electricity Board's nuclear power station which appeared on p 42 of our last issue, lack of space precluded full acknowledgement of the contracting group. The station was designed by the GEC Simon-Carves Atomic Energy Group and the detailed responsibilities are as follows:

THE GENERAL ELECTRIC CO LTD: Main contractors—responsible for design of reactors, mechanical and electrical equipment. This includes: fuel charging machines, blowers, control rod mechanisms, specialized instrumentation (including burst slug detection), control and safety equipment, turbines, alternators, motors, switchgear, transformers and cables etc.

SIMON-CARVES LTD: Design of heat exchange system and civil engineering design

MOTHERWELL BRIDGE & ENGINEERING CO LTD: Fabrication and erection of pressure vessels

JOHN MOWLEM (SCOTLAND) LTD: Civil engineering contractors. Consulting engineers to the South of Scotland Electricity Board were: Kennedy and Donkin, London

The table on p 56 of the same issue contained an error in respect of this station. The steam mass flows should be—h.p. 1,145,000, l.p. 556,000 lb/h. Values in the table on p 47 are correct.

New steel being developed for Bradwell pressure shell

SOME ENGINEERING PROBLEMS OF NUCLEAR POWER STATIONS

by Sir Claude D. Gibb, KBE, FRS

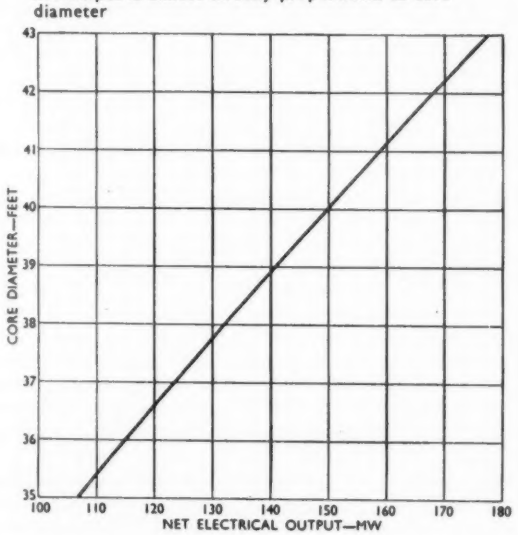
Entitled ' Some engineering problems in connexion with the industrial applications of nuclear energy ', the forty-third Thomas Hawksley lecture of the Institution of Mechanical Engineers was given in London on February 15, 1957 by Sir Claude Gibb, Chairman and Managing Director of the Nuclear Power Plant Co Ltd. Britain, he said, needs today nuclear power almost as a matter of national salvation. Power—particularly in the form of electricity—was the only way to raise living standards and the greatest single factor in increasing industrial productivity was the increase of per capita electricity consumption. Sir Claude discussed the background of the British nuclear power programme and concluded that the natural uranium, graphite-moderated, carbon dioxide-cooled reactor was the most suitable type for the early stages. He had the highest praise for the Calder Hall designers who had produced a nuclear power station which was the envy of the whole world. The latter part of Sir Claude Gibb's lecture, which is reproduced in abridged form here, dealt with some engineering aspects of this type of station and in particular with the one at Bradwell.

NUCLEAR CALCULATIONS for a natural-uranium, graphite-moderated, gas-cooled reactor are extremely complex and are greatly speeded up by a special form of analogue computer. Nuclear physicists will state the minimize core size and the amount of uranium to obtain criticality. From this, and considerations of fuel rating the output expressed in megawatts from varying core dimensions may be determined (Fig. 1).

An increase in core size above the critical pays a handsome dividend due to reduced leakage and the possibility of flux flattening by absorber, thereby increasing the mean rating of the fuel.

The maximum rating of the fuel in the centre channel, which very largely sets the seal on the reactor economy, is determined by the maximum temperature permissible in the fuel rod and the can. These factors largely determine the mass flow of the gas and its inlet and outlet temperatures.

Fig 1 At constant maximum rating for a typical reactor, net output is almost directly proportional to core diameter



The boiler designer must now decide how much steam, and at what pressures and temperatures it can be supplied to the turbines, whose designers then provide a figure for electrical output. The designers of the duct work and gas circulators then determine the pressure drop in reactor, ducts, and boilers and, with a known mass flow, can design their portions of the plant.

Once the pressure-vessel designer has been given a preliminary estimate of the core dimensions, he can consider whether to use a cylindrical or a spherical vessel which so obviously is to be preferred if considered purely as a vessel to contain gas pressure. But he must consult the designers of the fuel element charging and discharging gear, because it requires space above the reactor core and also almost riddles the crown of the vessel with holes or tubes to provide access to the fuel channels. The vessel designer must also know the number and size of the gas ducts. He must also consider how to transmit the very considerable weight of graphite and uranium through the vessel to the foundations without complicating and increasing locally the stresses resulting from the gas pressure. That harassed designer also has to consider the changes in temperature between inlet and outlet gases and the stress pattern induced in consequence, and then face the crowning problem of the irradiation effects upon the shell materials available to him.

The designer of industrial nuclear stations must never lose sight of his prime object which is to produce electricity at the lowest cost possible consistent with safety and reliability. Fig. 2 shows how the capital cost falls with output. In practice the curve would be in a series of steps corresponding (amongst other factors) to steps in the

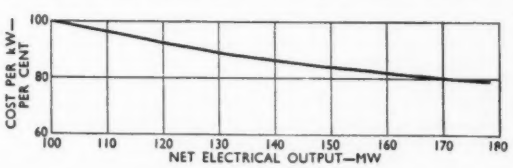


Fig 2 For the same conditions as Fig 1 capital cost falls with output

ON DISCUTE quelques détails du type anglais de la pile à l'uranium naturel et à réfroidissement au gaz. En ce qui concerne les éléments combustibles, on est d'avis que l'attention particulière doit être faite à la configuration de la surface de transmission de chaleur, si l'on veut obtenir un rendement maximum. Au sujet de sécurité, on décrit un système dans lequel la température du combustible ne peut pas monter aux niveaux dangereux même quand les souffleurs font défaut. On discute la construction des souffleurs et l'on en esquisse le développement futur. La commande de vitesse au moyen d'un moteur à fréquence variable est préférée à d'autres solutions. La canalisation de gaz doit être concentrée dans un plan pour éliminer la nécessité des joints de dilatation universels. Le cycle de vapeur à double pression, dans lequel la vapeur à basse pression est surchauffée pour atteindre la température de la vapeur à haute pression, est jugé indispensable pour obtenir le rendement maximum dans le réacteur de ce type.

ES WERDEN ERÖRTERT einige Bauartdetails des britischen Typs des gasgekühlten Natururanreaktors. Was Brennstoffelemente anbelangt, ist der Verfasser der Meinung, dass besondere Aufmerksamkeit der Konfiguration der Wärmeaustauschoberfläche geschenkt werden muss, falls man den grösstmöglichen Nutzeffekt erzielen will. Betreffs Sicherheit wird ein System geschildert, in welchem die Brennstofftemperatur nicht zu einem unerwünschten Niveau steigen kann, auch wenn die Hauptgebläse versagen. Man erörtert die Gebläsebauart und die diesbezüglichen künftigen Vervollkommnungsmöglichkeiten an. Geschwindigkeitsregulierung mittels eines Motors veränderlicher Frequenz wird anderen Systemen vorgezogen. Sämtliche Gasleitungen sollen in einer Ebene angeordnet werden, damit keine Universal-Ausdehnungsverbindungen unentbehrlich werden. Der Verfasser glaubt, dass der Doppeldruck-Dampfzyklus mit Niederdruckdampf, welcher bis zur vollen Hochdrucktemperatur überhitzt wird, durchaus notwendig zur Erlangung des Höchstwirkungsgrades in diesem Reaktortyp ist.

SE ESTUDIAN algunos aspectos del diseño del tipo británico de reactor de uranio natural enfriado por gas. En cuanto a los elementos combustibles se considera que debe prestarse especial atención a la configuración superficial del traspaso de calor, para conseguir la máxima eficiencia. Se describe un sistema de seguridad, con el cual la temperatura del combustible no puede subir hasta niveles inaceptables, incluso en el caso de fallar el ventilador principal. El diseño de ventiladores es discutido y se comentan futuras evoluciones. El control de velocidad por motor de frecuencia variable es preferido a otros métodos. Los conductos de gas deben colocarse todos en un mismo plano, a fin de evitar la necesidad de juntas de expansión universales. El ciclo doble de vapor a presión con vapor de b.p. recalentado hasta la temperatura de a.p. completa se considera esencial para la máxima eficiencia de este tipo de reactor.

ОБСУЖДАЮТСЯ НЕКОТОРЫЕ детали конструкции великобританского типа реактора на природном уране с газовым охлаждением. Насчет топливных элементов автор считает, что особое внимание нужно обратить на очертание поверхности теплопередачи, если желательно добиться максимальной производительности. Что касается дела безопасности, то описывается система, в которой температура не достигает недопустимых уровней, даже в случае, когда главные воздуходувки перестают действовать. Описывается конструкция воздуходувок и намечаются линии их усовершенствования в будущем. Управление скоростью посредством мотора переменной частоты предпочитается другим методам. Газовые трубопроводы должны быть сосредоточены в одной плоскости, чтобы избежать необходимости универсальных расширительных соединений. Паровой цикл двойного давления, в котором пар низкого давления перегревается вплоть до полной температуры высокого давления, считается существенным для достижения максимальной производительности в реакторах этого типа.

reactor-vessel wall thickness. The Calder Hall reactor vessels were of 2-inch thick special mild-steel plate but subsequent research and experimental weldings have shown that site welding of 3-inch plate is now possible and, with further experience, still thicker plates will be used in future with corresponding increases in pressure and efficiency. To change from the vertical right cylinder vessels as at Calder Hall to spherical vessels enabling higher gas pressures to be adopted, necessitated finding solutions to many problems, not the least being the sealing of inlet and outlet gas paths from the walls to the core, doing this without adding appreciable temperature stresses to the already pressure stressed walls (Fig. 3).

A number of severe thermodynamic and mechanical problems are involved in the design of the fuel elements. With the magnesium alloy chosen for the new power stations, the maximum surface temperature is limited to approximately 842°F and the aim is to obtain the optimum between the conflicting demands of high outlet gas temperature, high heat rating in the fuel, and an economic pumping power. The choice of a suitable heat-transfer surface is further complicated by nuclear considerations.

The mechanical problems are concerned with the support of the elements in the channel, and the forces imposed on the fuel and canning material by the method of support. Consideration must also be given to the handling of the element during charge/discharge operations at power, and the strength of the element must be sufficient to resist damage under these conditions.

Natural uranium changes its crystalline structure at about 1,202°F and the considerable change in volume accompanying it can lead, especially if repeated several times, to the complete loss of mechanical strength and to the destruction of the can, thus allowing fission products to escape. Consequently, for the time being, the temperature at which this alpha-beta transition occurs dictates the temperature limit of the reactor.

Advances in fuel element design

For nuclear reasons, the shape of the uranium should be such that the ratio of surface to volume is small, in direct contrast to the requirements for maximum heat removal. With one cylinder per channel, the fuel-rod optimisation requires a diameter slightly over 1in. Uranium is such a bad heat conductor that with the reactor on load there is a temperature drop of about 212°F from centre to periphery of the fuel rod. A further, though smaller, temperature drop occurs at the boundary between uranium surface and can surrounding it. The temperature drop in can wall and fins is small but that between can surface and gas is appreciable.

To reduce the temperature drop, we should work at high Reynolds numbers; apply large secondary areas, and create surface configurations which produce high heat transfer with relatively low pressure drops.

High Reynolds numbers necessitate, in order to keep pumping power within acceptable limits, high gas pressures or short channels. The pressure is limited by the pressure shell, which is large and hot. Shortening of the channels leads to an increased diameter to height ratio of the core and thus reduced neutron economy, as well as uneconomic design of the pressure vessel.

Applying large secondary areas leads to increased neutron capture which, particularly with natural uranium, soon exceeds acceptable limits but also its thermodynamic effectiveness falls if the can fins become either too long or too close.

Hence it is to surface configuration that special attention must be given. The thermal conductivity in gases being low, the aim must be to scour the hot fuel element sur-

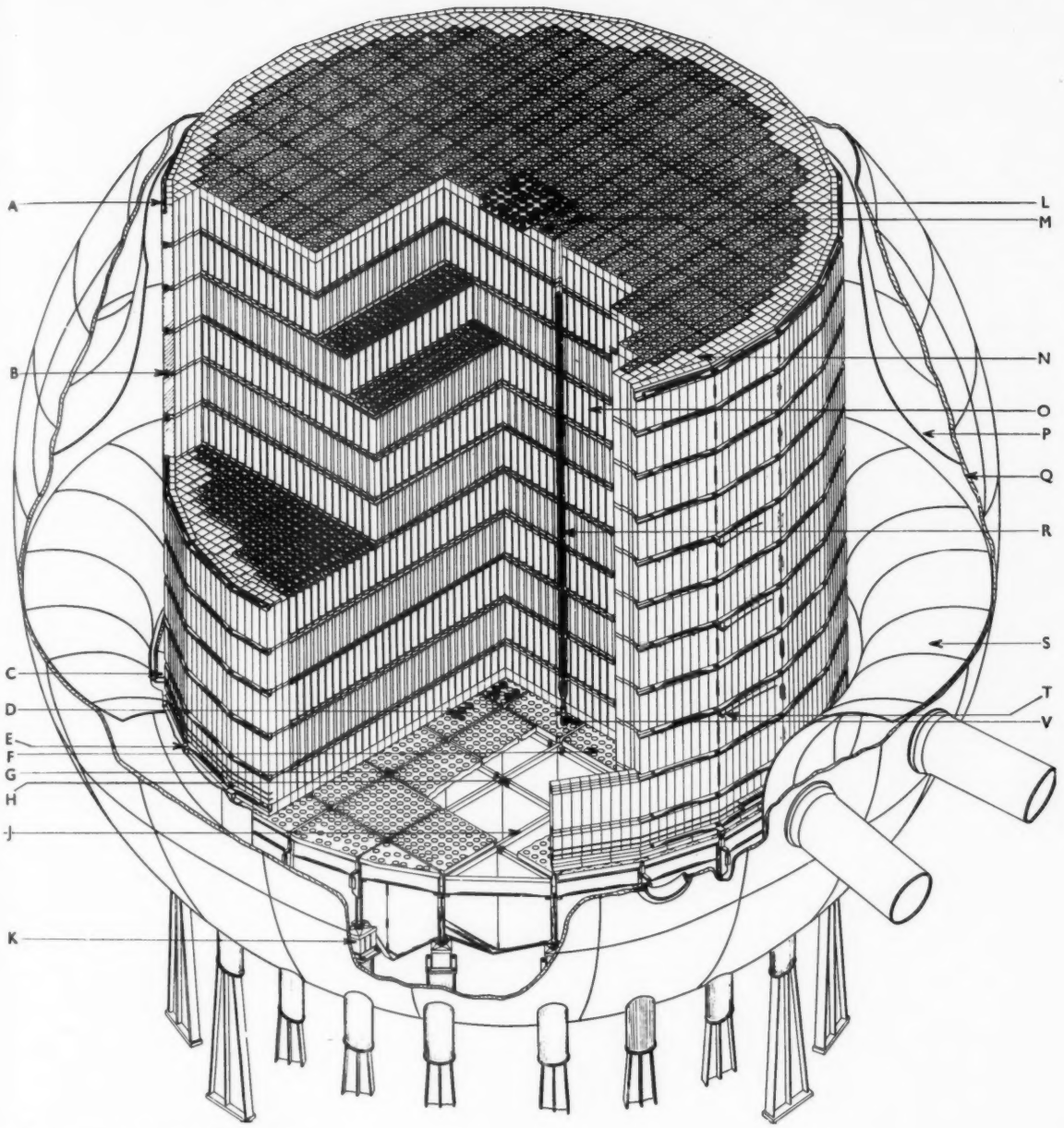


Fig 3 Isometric of Bradwell core shows—

A Topside restraint
B Intermediate side restraint
C Gas seal
D Graphite support bearing
E Bottom side restraint and radial keys
F Support plates
G Levelling screws
H Levelling pads
J Diagrid
K Roller supports
L Charge pan
M Charge pan support
N Reflector bricks
O Moderator bricks
P Gas baffle
O Pressure shell
R Fuel element
S Toroidal shield
T Wigner growth measuring device
V Fuel element support lantern

face continuously by cooling gas, which is as nearly as possible at bulk gas temperature. This is best achieved if the gas which has been heated by contact with the fuel element is periodically transferred to, and replaced from, the main gas stream. It is important that this process be accomplished with the formation of few free vortices, which tend to increase the pressure drop without correspondingly increasing heat transfer. A considerable advance has been achieved by such a development.

The uranium in a power reactor will be at temperatures in the range 392° to 1,112°F, depending upon the position of the element in the core. At the higher temperatures, the uranium is relatively weak and there is also evidence that creep may be accelerated by irradiation in the low-temperature portion of the reactor. Therefore the uranium must be arranged so that the forces imposed by its own weight are relatively small or, alternatively, supported continuously along its length to resist distortion.

For several reasons, including the containment of maximum size of core in a given pressure vessel, length of duct work, better natural circulation in the event of circulator failure, stress and differential movements in the core and pressure vessel, a core with vertical channels is preferable for power reactors. Refuelling has therefore to be carried out completely either from above or below, or by passing new fuel in at the top and spent fuel out of the bottom. The last method has many attractions but requires twice the equipment and cannot be justified economically. Systems for refuelling from below have been devised, but they involve the insertion of relatively complex mechanisms into the pressure vessel and operating rams into the core. Thus it is possible that their reliability may be less than the simple mechanisms which are gravity assisted when charging from above.

It is at least highly desirable that refuelling on load be carried out without interference to the control system. This implies the use of separate standpipes for refuelling and control rods. The necessity to achieve a minimum ratio between fuel channels and control rods in the core determines a minimum pitch of the control-rod standpipes. The problem is to be able to insert charging standpipes between the control standpipes without weakening the pressure vessel, while maintaining adequate strength and shielding properties of the reactor-roof biological shield, and achieve satisfactory coverage of fuel channels below the charging standpipes and avoid interference between the control rods and charging mechanism which has to be inserted into the vessel (Fig. 4).

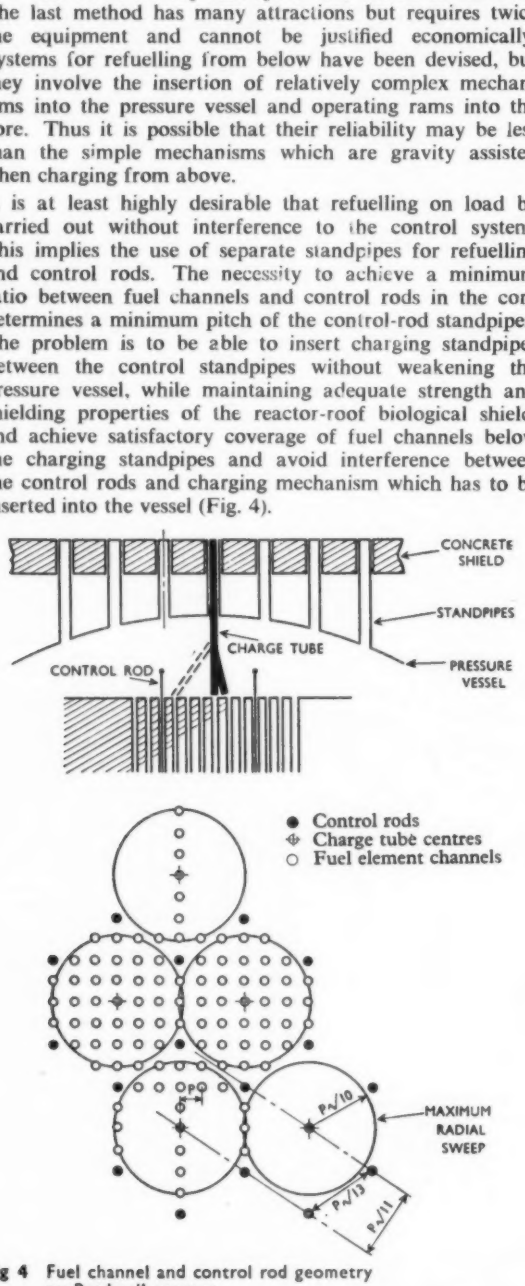


Fig 4 Fuel channel and control rod geometry on Bradwell reactor

It is now generally accepted that the gas-cooled graphite-moderated reactor does not present any hazard to the general public. Equally important, although not generally appreciated, is the fact that by careful design, it can be arranged that the reactor will not suffer serious damage due to the failure of its control or main cooling systems.

If at any time the ratio of the heat output to coolant flow exceeds the design value, overheating of the fuel will occur. An increase in this ratio can be due either to an increase in heat output or a decrease in coolant flow. It is essential that under either condition, the rise in fuel temperature shall be a minimum.

The most likely cause of increase in reactor power is withdrawal of the control rods. It is very simple to arrange the maximum rate of withdrawal so that maloperation at start-up cannot produce dangerous power surges. Reduction of coolant flow due to a failure of the main circulators would cause a more rapid rise in fuel temperature and particular attention must be paid to maintenance of an adequate flow at all times.

Elaborate systems of protection are provided to ensure immediate reactor shut-down following failure of main circulators, excessive gas pressure, excessive fuel temperature, and excessive power level, but when considering the inherent safety of the reactor, the reliability of the protection systems cannot be assumed.

The most serious case to be considered is, therefore, coincident failure of the main circulators and the trip circuits.

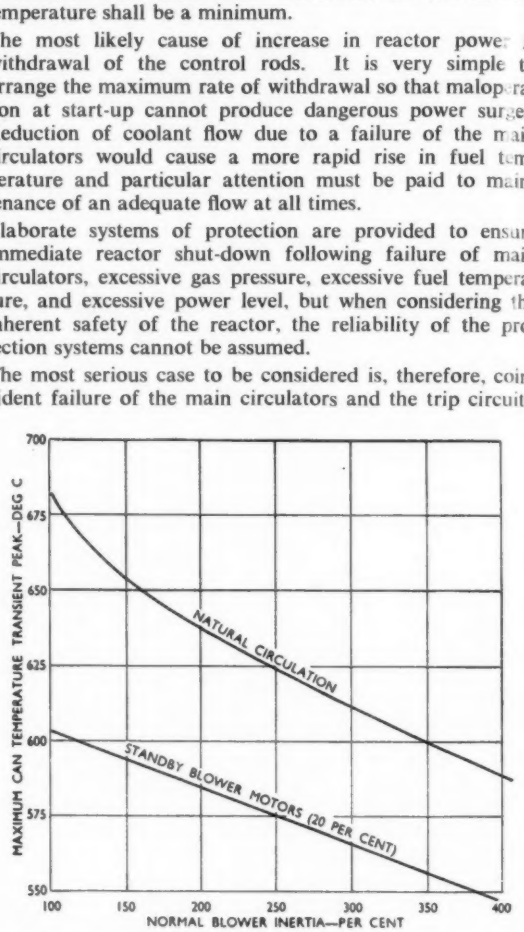


Fig 5 By increasing the impeller inertia, a substantial reduction in max. can temperature following a blower failure can be obtained

Under this condition the transient temperature rise of the fuel elements depends upon three main factors:

1. The negative temperature coefficient of reactivity
2. The run-down time of the main circulators
3. The capacity of standby coolant plant and the natural circulation inherent in the coolant circuit design

As soon as the coolant flow falls, the fuel temperature rises and because of the negative temperature coefficient, the power starts to fall. If the rate of change of flow is small enough, the power falls almost in step with it and there is only a slight rise in fuel temperature. However, the collapse of power cannot follow rapid reductions in flow and the rise in temperature can be excessive.

The rate of fall of flow on failure of the main circulator drives can be reduced by increase in the inertia of the main circulators (Fig. 5). By careful design of the coolant circuit, it is possible to achieve a sufficient flow by natural circulation to remove the heat and keep the fuel element temperature only slightly above the normal operating level when ultimately the circulators come to rest. The

provision of auxiliary circulator drives which automatically take over and maintain forced circulation further limit both the maximum and final fuel temperatures.

During the transient following circulator failure, the increase in coolant temperature causes an increase in coolant pressure which, if great enough, would cause the safety valves to lift. With a suitable run-down time of the main circulators, this blow-off can be prevented.

The fracture of a main duct or other portion of the pressure circuit with consequent loss of coolant is a possibility which must be considered in the mechanical design of these components and, particularly with the expansion joints, long time life tests with pressure and temperature cycling are necessary researches. Should, however, failure occur, with auxiliary drives to the circulators maintaining them at 20% normal speed, the fuel temperature can be maintained only slightly above the design value with the coolant at atmospheric pressure. With natural circulation, while the temperature rise is considerable, it is still appreciably below the melting point of the fuel cans.

In the construction on site of large vessels made from thick plates brittle-fracture is a definite hazard since the danger of this increases with the size of the vessel, the thickness of the plates and the depth of the welds which, besides increasing the stress due to welding, increases the difficulty of locating defects. Once the vessel has been constructed and stress relieved the danger of brittle-fracture is diminished but not eliminated, since, although the plant operates at a temperature well above the transition temperature of all steels, it is subjected to a pressure test while cold before being charged, it is almost certain to be allowed to cool sometimes during its life and it is known that irradiation raises the transition temperature of the steel.

The danger of brittle-fracture in pressure vessels can be reduced by using a low-carbon, high-manganese, aluminium-killed steel with a low transition temperature, that is, a high notched bar toughness at low temperature. But such steels have poor creep properties at high temperatures. Silicon-killed carbon steel has been used extensively in high-temperature plant and has good stress/temperature properties but would be likely to fracture in cold weather.

Work on new high temperature steel

One solution is to use a silicon-killed, high-manganese, low-carbon steel and thus obtain the high-temperature properties associated with boiler quality steel suitable for high-temperature service combined with a fairly low transition temperature. Another solution is to obtain, by the addition of alloying elements, a steel with satisfactory stress/temperature properties and a sufficiently low transition temperature. A steel that appears to fulfil those requirements has been developed and is under long-term high-temperature/high-stress testing.

An obvious solution to this difficult problem is a double-shell vessel in which a thin inner shell that takes the temperature is made from a suitable steel while a thick outer shell that takes the pressure is kept cool and can therefore be made from an aluminium-killed steel. Like many first solutions in engineering problems, the difficulties increase as detail design develops. The double-skinned reactor vessel becomes less promising when endeavouring to accommodate gas ducts, control rods, and charge-discharge standpipes.

Were it possible to increase gas temperatures to the point that austenitic nickel-chromium steel became economic for the pressure vessel, the problem might be simplified, since this steel combines a high resistance to brittle fracture with good mechanical properties at high temperature.

Allowance in design must be made for the corrosion by hot carbon dioxide on the pressure vessels, ducts, circulators, and heat exchangers. Experiments have determined the wastage rates for the different steels used and adequate margins allowed.

The gas blower can be of the centrifugal or axial type. Mechanical, rather than aerodynamic problems, tend to predominate and the design will be influenced mainly by station layout, the requirement for gas-tight enclosure and any limitations of speed imposed by the type of drive. On the Calder Hall plant a centrifugal design was selected. In general the optimum speed for this type is much lower than that of the axial, and in this case the design was suitable for the Ward Leonard drive. The large diameter of the impeller, however, introduced a severe problem in obtaining a satisfactory pressure casing and a heavily ribbed structure is required to resist distortion at the sides. The horizontal joint also introduced gas sealing problems because of its size and shape. With regard to station layout, the centrifugal blower, unless mounted vertically, must impose a 90° change of gas flow in the horizontal plane and this is not always desirable when considering duct expansions and general aesthetics.

If the blower drive is suitable for a rotational speed of, say, the order of 3,000 rev/min, then the duty for a gas-cooled reactor can be met by a single-stage axial design. The diameter of the pressure casing can be reduced compared to the centrifugal design, and this enables the impeller to be inserted or withdrawn horizontally to provide a better form of joint in the vertical plane which avoids non-circular shapes (Fig. 6). The casing lends itself to

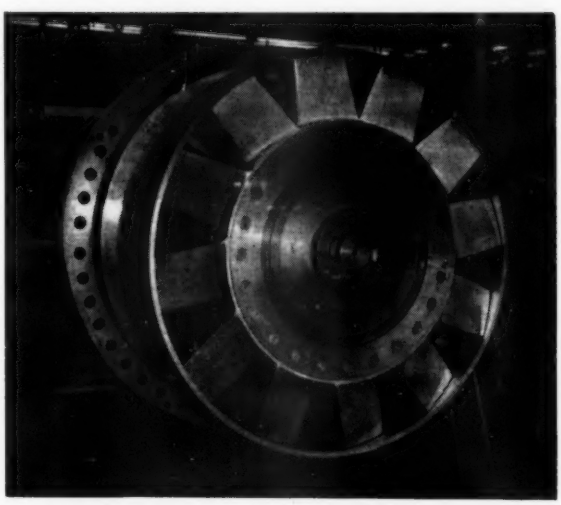


Fig 6 Coaxial diffuser on a single-stage axial-flow blower provides highest efficiency

fabrication and is designed on normal pressure vessel principles using dished ends. Large flat surfaces are avoided and the resultant increased rigidity of the vessel ensures that flanged joints are not distorted by pressure to produce gas leaks.

To attain a high efficiency with a single stage of axial-flow blading it is necessary to provide an efficient diffuser at exit and to keep the axial velocity of the gas as low as possible.

The single impeller can be conveniently accommodated on an overhung shaft and only one gas seal is required. A seal suitable for the gas pressures and speeds of these special blowers has been developed from hydrogen-cooled

alternator practice. The seal requires oil and the system must be designed to prevent contamination of the gas in the circuits. Present development work is aimed at a gas viscosity plate type of seal which will avoid the use of oil, but much work remains to be done in this direction.

A further possible line of development is the use of gas bearings to enable the complete enclosure of blower and motor in a gas-tight casing. Apart from the problems of suitable gas bearings, there are others such as the cooling of the motor and the possible contamination with active matter which would complicate maintenance. Although an enclosed design would have advantages from considerations of gas leakage and layout, it is a matter for conjecture whether these advantages would outweigh additional complications. If a suitable gas viscosity seal can be developed then this may prove to be an attractive solution to the problem.

The main problem associated with the blower drive is the provision of a variable-speed range. During operation as a base load station the output must be varied between about 70 and 100% full load, and for the highest efficiency the reactor gas outlet temperature should be maintained while the mass flow of gas is reduced by change of blower speed. Apart from retaining good steam conditions by this method, there is an appreciable saving of blower power. At 80% load, for example, the blowing power is reduced to about one half of the normal requirement, and on a large station this may mean a saving of 10 or 15 MW.

Speed variation between about 70 and 100% of normal speed is therefore required on this account, and it is also desirable to have a small overspeed margin to cater for unknowns in the design which might otherwise prevent the guaranteed station output being obtained at design temperatures. In providing such a speed range, it is usually possible to specify a wider range of, say, 5:1 without materially increasing the cost of the equipment. Being able to run the blowers at low speeds or at any desired intermediate value up to full load increases greatly the flexibility of operation, and can help to avoid undue thermal cycling of fuel element temperatures.

The speed variation may be provided in several ways, for example, by variable-frequency or variable-voltage supplies to electric motors, by hydraulic couplings or by direct steam-turbine drive. Reliability is the outstanding consideration and a squirrel-cage induction motor, used in conjunction with a variable-frequency supply or alternatively a hydraulic coupling, is to be preferred. The variable-frequency drive is superior in having good efficiencies down to quite low speeds, and the power savings at part loads can be shown to justify the extra capital cost of auxiliary turbo-alternators to provide the supply. These auxiliary turbo-alternators reduce the output required from the main machines and therefore ease the turbine exhaust problems on the larger machines.

One duct per boiler preferred

Gas cooling of the reactor requires a number of ducts of large total flow area to transfer the heat output to the boilers even though gas pressures of about 10 atmospheres are used. The main problem in providing the flow area necessary to give an economic pumping power is to limit the duct diameter to a dimension which will allow the thermal expansion of the pressure vessel, boilers, and ducts themselves to be accommodated. The diameter should also be such that severe problems are not introduced into the design and manufacture of gas valves required for isolation and possibly control.

The choice of the number and diameter of the ducts is closely related to the boiler design, and a compromise must be found for both of these, although the number of ducts per reactor and the number of boilers need not necessarily be equal. In general, however, the provision of a number of small ducts for each boiler circuit is not economically desirable and necessitates the control of a large number of valves. One duct per boiler is usually a better solution, and the use of restrained bellows units to accommodate the expansion avoids high thrusts on the pressure vessels and boilers.

If the ducting can be arranged in one plane the bellows units are required to rotate in only that plane and a flexible torque rod mounted inside the unit can replace the external hinge pins normally used. This avoids the problems associated with high bearing loads on the hinge pins and also the necessity for ensuring adequate lubrication to reduce friction.

Some points on turbine design

The gas temperature at outlet from the reactor is restricted to about 750°F with magnesium fuel cans, and steam conditions are therefore representative of practice fifteen to twenty years ago. Overall cycle efficiencies with a normal condensing steam cycle would be about 26%, allowing for a reasonable temperature difference between gas and steam in the boilers, but this efficiency has been raised to over 28% by the application of the dual pressure cycle. Consideration has been given to other applications in order to improve upon this efficiency and these include triple pressure cycles, single pressure with reheat, and single pressure with separate superheating from external sources. In general, the dual pressure cycle offers a reasonable compromise between gain in efficiency and complexity and cost, and also offers the advantage that it can facilitate the control of reactor gas temperatures.

In this cycle a quantity of steam is generated at a low pressure, say about 200 lb/in², and the remainder at a much higher pressure, say, 700 lb/in². The choice of pressures for optimum efficiency is dependent upon the degree of feed heating and the ratio of h.p. steam quantity to l.p. The steam pressures at the optimum efficiency produce a high wetness at the turbine exhaust and, because of low temperature, there is a large volume flow of steam for a given output in comparison to modern machines. The design of the exhaust is therefore the limitation on unit output, and with two exhausts an output of 50-60 MW is achieved at a speed of 3000 rev/min compared to 120 MW for a plant operating at 1500 lb/in² and 1050°F. The steam wetness and volume flow show little reduction in moving from the optimum efficiency and there is no incentive to lose station output for only a small improvement in these parameters. Consideration has to be given to the use of stellited blades, water extraction belts and a reduction of blade peripheral velocities in order to obtain a satisfactory design of turbine. The use of three or four exhausts will be necessary to attain unit outputs of 100 MW—moderate by present-day standards.

To obtain maximum cycle efficiency it is desirable to raise both the high-pressure and low-pressure steam to the same temperature in the superheater section of the boiler. Large temperature differences are created between the low-pressure steam and the steam in the turbine at the low-pressure injection point, and care has to be taken to avoid problems of differential expansion.

It has been possible to mention a few only of the many problems associated with the development of industrial nuclear power and those only briefly. Many colleagues in the team of designers with whom I am proud to work have contributed to these notes, and my acknowledgement and thanks are gladly given to them.

The Berkeley power station will use electronic computers for gas activity monitoring

Data processing for burst slug systems

by D. D. Bowen Sunvic Controls Ltd

IN GAS-COOLED POWER REACTORS the fuel elements operate close to their critical temperatures and it is most important to provide adequate warning of can bursts.

These are of two types: pin-holes and major splits, each producing combustion of the uranium if oxygen is present in the coolant. The uranium oxide formed from combustion re-seals the pin-hole type fracture, so it is important to know each time this occurs, since adjacent fractures in a weld may lead to a major split. The reactor operator therefore requires both short term and long term channel activity information.

Consider first the short term requirement. If the reactor is operating under design conditions, can failures should be rare so, although it is essential to monitor all channels at least once per half hour, the operator should ideally only be advised of abnormal activities.

Limitations of graphic system

At Calder Hall, each core has 1696 channels and for gas monitoring they are grouped in fours in eight sectors. (NP Nov 56, p 287.) Each sector has its own precipitator and the activity readings are recorded on a chart recorder which prints 53 miniature graphs in axes 1½ by 1 in. The new stations, however, will have nearly double this number of channels and so the graphical method becomes rather unwieldy. Furthermore, it can be shown that the accuracy is severely limited by the small size of the records.

In considering a new system, the principle adopted is that the great mass of activity counts are normal and are of little immediate interest. What the control engineer needs is instant notice of any abnormality with the facility of knowing the sequence of events leading to it. For the AEI-John Thomson power station at Berkeley, Sunvic Controls Ltd have developed a new system of data handling—the *Computer Display Method* (Fig. 1). In this, the gas sampling system, electrostatic precipitators, scintillation counters and head amplifiers are generally similar to those at Calder Hall. Where it differs is that, instead of a ratemeter, each precipitator unit uses a scaler which passes a binary count to a computer in which the information is stored. The scaler has no calibration errors, the accuracy depending only on the statistical count rate error for random pulses and the scaler input paralysis time. For 1200 counts—a typical background—the probable error would be less than 3%, progressively decreasing for higher count rates. The input counter paralysis time would produce an error of less than ½%, and this would become negligible if the differential of successive count cycles is calculated.

All computer information is displayed to 3 significant figures and offers more than four times the discrimination obtainable with the recorder display method, without the electrical and mechanical performance variations inseparable from the latter.

Absolute and differential levels

The most sensitive method of examining channel activities is by measuring rate of change of activity in each channel group. With the recorder system this requires half-hourly scrutiny of the individual graphs but the computer uses a cyclic memory storage system which notes and compares the half-hourly counts, storing all relevant information, and notifying the operator only of any significant increment. To cover successive differential increments, each below the maximum alarm setting for a group, it is also necessary to provide absolute activity levels for the channels, preferably closely related to their normal individual background levels.

The long-term requirement is for statistical record purposes and requires that a background count of each group of channels be recorded at regular intervals. From this, the Technical Records Staff can plot channel activities in which they are interested for periods of 7 to 14 days.

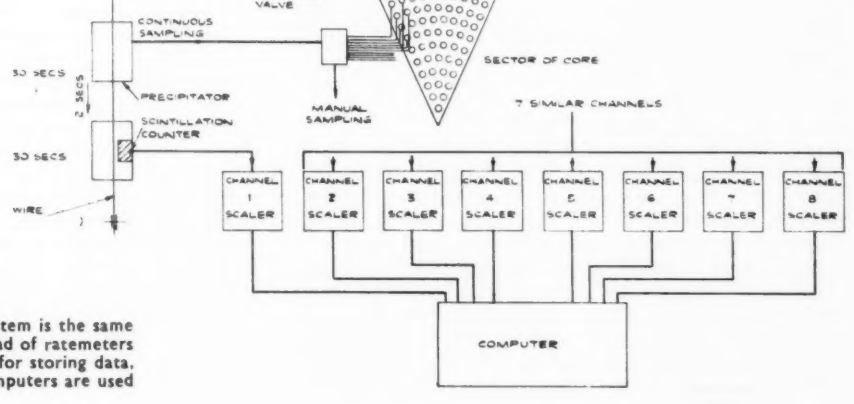


Fig 1 The detection system is the same as at Calder Hall but instead of ratemeters and graphic recorders for storing data, scalers and electronic computers are used

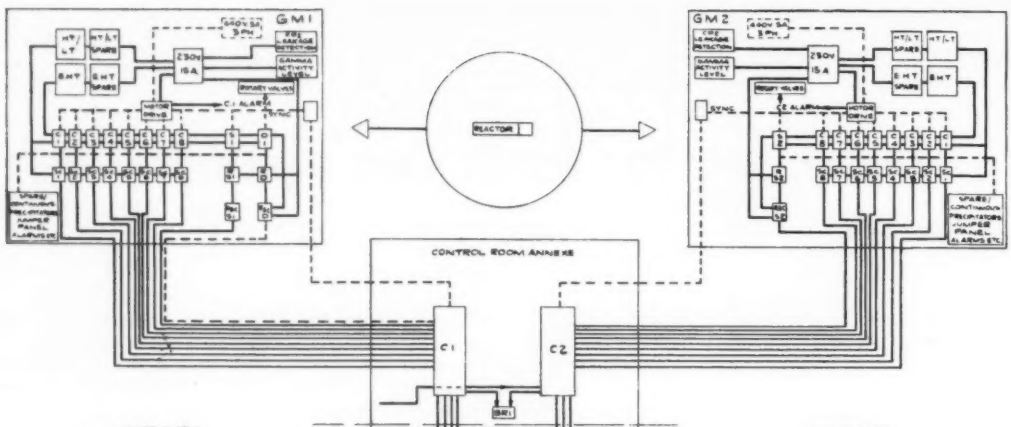


Fig 2 A single reactor has two gas monitoring rooms (GM1, GM2), the computers being located in an annexe in the main control room which contains only the minimum of equipment

Each computer used operates two electric typewriters, one for log recording or alarm condition print-out, and the other for back reading or examination of the reference levels set for differential and absolute alarms (Fig. 2).

The control engineer may present the logging time interval as desired. He then obtains a complete reactor scan log print-out giving precipitator, channel group, time and absolute activity to 3 significant figures. For a computer covering 400 groups of channels, 8 readings are printed every half minute for 25 minutes.

If a damaged cartridge is located, it may be necessary to examine the relevant grouped channel activities for the 24-hour period previous to the burst. This is done by a 24-hour progressive memory store capable of holding 48 readings per group of channels together with the relevant chosen differential and absolute reference levels. During any one scanning cycle the operator can select any group for automatic print-out of the previous 24 hours' activity record.

Fig. 3 gives the schematic layout of an eight-precipitator computer unit designed to meet the short- and long-term display and alarm requirements. Commencing at reactor start-up, the sequence is as follows:

System operation

At the end of each 30-second period the master drive motor moves the 50-way valves to their next port, and simultaneously drives the precipitator wires to their next collect/count positions. This takes 2 seconds, during which each scaler reading is transferred to the computer, and is followed by a clearance to zero of all scalers ready for the next count before the wires come to rest.

As the wires commence to move, WAIT FOR THE NEXT COUNT (1) is operated. The PRECIPITATOR SELECTOR SWITCH is in the HOME position (*i.e.* Scaler 1 output). The ten most significant binary digits are transferred to the TEMPORARY STORE (2). The STEP SELECTOR (3) moves the PRECIPITATOR SELECTOR SWITCH to position 2 (*i.e.* Scaler 2 output) and the selector is then checked for HOME position by (4) against (5). As it is OFF NORMAL, the reading from Scaler 2 is next transferred to the TEMPORARY STORE. This cycle continues until the 8th Scaler reading has been transferred, when the SELECTOR TEST indicates HOME (*i.e.* back to Scaler 1). The total time taken for the transfer of the 8 readings is less than 100 milliseconds.

The return to HOME position of the SELECTOR TEST (4) initiates the next computer cycle. First a TEST IF START (6) is made and until the arrival of the 401st reading the answer is YES. The reading from Scaler 1 is then located in the TEMPORARY STORE and written into the PERMANENT ABSOLUTE ACTIVITY STORE (9). The STEP PRECIPITATOR SELECTOR (10) moves the PRECIPITATOR SELECTOR to Scaler 2 output. TEST SELECTOR (11) checks for HOME position against (5). As it is OFF NORMAL the reading from Scaler 2 is next written into the PERMANENT ABSOLUTE ACTIVITY STORE and this cycle repeats until the 8 readings have been written in. The TEST SELECTOR (11) HOME initiates the TEST IF START (12). Since the START COUNTER (7) carries a 400 unit bias, the answer is YES and the START COUNTER is stepped 1 unit by the STEP START COUNTER (14). The PERMANENT ABSOLUTE ACTIVITY reading from Scaler 1 is located and fed into TEST AA (16) where it is compared with the STORED REFERENCE AA (17) previously chosen by the operator. Should the reading be excessive, ALARM (20) will be operated and the ABSOLUTE ACTIVITY reading will be transposed and printed out together with its precipitator and channel identification. If, however, the reading is excess negative or zero, the ALARM sounds but print-out is not initiated since the cause is most likely to be a computer circuit failure.

After the test for absolute activity, the precipitator selector is stepped to Scaler 2 PERMANENT ABSOLUTE ACTIVITY reading by (18). The selector position is checked for HOME by (21) against (5) and since it is found OFF NORMAL the procedure is repeated for Scaler 2 AA reading. When the HOME position is again reached TEST FOR LOG TIME (22) is operated. A PRINT-OUT TIME SELECTOR (23) is preset for ½, 4, 8, 12 or 24 hourly intervals for automatic logging; if the answer is YES the PERMANENT ABSOLUTE ACTIVITY reading for Scaler 1 is transposed and typed

out together with its precipitator and channel identification. The STEP SELECTOR (25) cycle repeats until the 8 readings have been logged.

The SELECTOR HOME (26) initiates the TEST IF BACK READING REQUIRED (27). If the SET CHANNEL REQUIRED (29) is in the HOME position the computer returns to the WAIT FOR NEXT COUNT (1).

If the operator decides he requires a channel group back reading print out, he manually sets the required precipitator on an 8 position switch (30) and also manually sets the required channel group on a 6 × 10-way switch (29).

When the TEST IF BACK READING REQUIRED (27) is now initiated the back reading unit will continue to be by-passed until the channel required (29) and the channel indicated (28) correspond. The correspondence will last for 30 seconds and during this time the 48 back readings for this group of channels will be printed out (less if the computer has not run for 24 hours).

The sequence is as follows. The ½ HOUR PULSE UNIT (37) progresses the 48 ½-HOUR COUNTER (36) so that the first back reading to be located and printed from the ABSOLUTE ACTIVITY STORE is always the last to have been written in. Having located this reading it is printed out, and then the BACK READING COUNTER (35) is stepped by (33). TEST BACK READING COUNTER (34) checks and repeats BACK READING print out cycle until all obtainable readings have been transferred, *i.e.* when 48 ½-HOUR COUNTER (36) equals BACK READING COUNTER (35), the computer resets to WAIT FOR NEXT COUNT (1).

At the end of approximately half an hour the computer completes a scan of all channel groups. Then on arrival of the 401st reading, since there is now a complete store of ABSOLUTE ACTIVITY readings, the TEST IF START (6) answer is thereafter NO, the scaler reading therefore being fed into CALCULATE AND STORE DA (8). The previous ABSOLUTE ACTIVITY is located from the permanent store and the two readings compared. The difference is put into temporary storage, and as before the ABSOLUTE ACTIVITY reading is then fed into the PERMANENT AA STORE (9).

When TEST IF START (12) is reached the answer is NO and the DIFFERENTIAL ACTIVITY from the temporary store is tested for limits against the stored reference differential (13) against (15). Excessive DA operates the PRINT OUT (19) and ALARM (20).

The new power stations have two reactors and both will be regulated from the same control room However, to simplify the description let us assume only one reactor. This will have two gas monitoring rooms GM1 and GM2 (Fig. 2). For stress reasons, it is undesirable to bring all the sampling pipes out of the pressure vessel on the same side: it is better to have a symmetrical arrangement with two rooms. The plant will have two computers and they will be situated in an annexe to the control room proper leaving only the bare minimum of burst slug instrumention for the control engineers to watch. Details of typical equipment are:

Control Room

Two electric typewriters (LA1, LA2) to display a normal log of all channel groups or identify and display excessive differential or absolute activity measurements. Two single-point 10in. high-speed recorders (Rec S1, S2) operate from a spare precipitator in any group after an alarm has been given, or if the operator decides he requires the facility. These recorders are slave repeaters of identical recorders adjacent to the relevant spare precipitators in the Gas Monitoring rooms.

LES NOUVEAUX RACTEURS de puissance britanniques auront environ 3000 canaux de combustible, qui devront être controlés toutes les demi-heures pour assurer qu'aucun élément combustible ne soit pas avarié. Ceci se fait au moyen de la précipitation électrostatique des spécimens du gaz réfroidisseur sur un fil, le comptage de l'activité étant exécuté par un scintillateur et photo-multiplicateur. On décrit dans cet article une méthode nouvelle de traiter l'information ainsi obtenue. Au lieu d'employer un compteur du taux de comptage et une batterie des enrégistreurs avec feuilles de petit format, ainsi que cela se fait à Calder Hall, on transforme le compte en un nombre binaire qu'on emmagasine sur un tambour magnétique d'emmagasinage, faisant partie d'une machine à calculer électronique. Les comptes obtenus pour les groupes de canaux toutes les demi-heures sont comparés automatiquement et l'opérateur n'est averti qu'en cas d'un changement significatif. On garde enrégistrements complets pour les périodes de 24 heures afin de pouvoir suivre l'histoire d'un défaut.

DIE NEUEN KRAFTREAKTOREN Grossbritanniens werden ungefähr 3000 Brennstoffkanäle haben, welche jede halbe Stunde kontrolliert werden müssen, um zu sichern, dass kein Brennstoffelement beschädigt wird. Dies wird durch elektrostatische Niederschlagung von Kühlgasmustern auf ein Draht zustande gebracht, wobei die Abzählung mittels eines Szintillators und eines elektronischen Photoverstärkers ausgeführt wird. Ein neues Verfahren zur Ausnützung der auf diese Weise gewonnenen Information wird im Aufsatz beschrieben. Statt einen Geschwindigkeitsmesser und eine Batterie von Registriergeräten mit Miniaturstreifen zu verwenden, wie dies in Calder Hall der Fall ist, wird das Zählungsergebnis in eine binäre Zahl umgewandelt, welche in einer magnetischen Aufspeicherungstrommel, die einen Teil eines elektronischen Computers bildet, aufgespeichert wird. Halbstündliche Aktivitätsabzählungen aus den Kanalgruppen her werden selbsttätig verglichen, und wird der Operator nur dann gewarnt, wenn eine bedeutsame Änderung stattfindet. Vollständige Registrierungs-Resultate für 24-Stunden-Perioden werden aufbewahrt, damit die Geschichte einer Störung verfolgt werden kann.

LOS NUEVOS REACTORES británicos para la generación de energía tendrán alrededor de 3.000 canales de combustible, los cuales deben revisarse cada media hora a fin de asegurar que ningún elemento combustible ha sufrido daños. Esto se efectúa mediante la precipitación electroestática de muestras del gas enfriador sobre un alambre, midiéndose la actividad por medio de un detector de destello y un fotomultiplicador. El artículo describe un nuevo método para manejar esta información. En lugar de usar un detector integrador y un grupo de registradores gráficos en miniatura, como en Calder Hall, se transforma la medición en un número binario y se deposita en un "almacén" de tambor magnético que forma parte de un computador electrónico. Las mediciones efectuadas cada media hora de la actividad de los grupos de canales son comparadas automáticamente y el operador es avisado únicamente cuando ocurre un cambio importante. Se mantienen registros completos durante períodos de 24 horas para trazar el desarrollo de una falla.

В НОВЫХ ВЕЛИКОБРИТАНСКИХ энергетических реакторах будет иметься около 3000 топливных каналов, которые нужно контролировать в получасовых промежутках, чтобы обеспечить полное отсутсвие аварии в топливных элементах. Это осуществляется электростатическим осаждением проб газового охладителя на проволоке, причем счет проводится при помощи сцинтиллятора и электронного фотоумножителя. В статье описывается новый метод обработки полученных таким образом данных. Вместо того, чтобы употреблять измеритель интенсивности и батарею самопишущих приборов с миниатюрными карточками, как это делается в Колдер Холле, результат счета превращается в двойственное число, которое хранится в магнитном хранящем барабане, входящем в состав электронной счетной машины. Получасовые счеты активности из групп каналов автоматически сравниваются, причем оператор предостерегается лишь тогда, когда происходит значительное отклонение. Полные записи за 24-часовые периоды сохраняются для того, чтобы можно было проследить историю аварии.

One multi-point 10in. high-speed recorder (Rec D) for monitoring the duct gas activity build up, usually before the filter. This is a duplicate of a similar instrument in the Gas Monitoring room, enabling the record to be followed in either position by change-over switching. Major and minor fault alarm annunciator as detailed in Fig. 2.

Control Room Annexe

In addition to the two computers, this contains one electric typewriter (BR1), to display 24-hour back readings, 48 in all, or proportionately if the reactor has not run for 24 hours. It is also used for recording and examining absolute or differential alarm reference settings in use or desirable.

Gas Monitoring Room

In each room there is a single-point 10in. high-speed recorder (S1, S2) operated from a spare precipitator, for manual scanning of individual channels in any group, either following an alarm or at the request of the operator. The recorders are slave repeated in the Control Room.

There is also a multi-point 10in. high-speed recorder (Rec D) monitoring the duct gas activity, and duplicated in the Control Room. Alarm indicators cover: Motor drive or Mains Supply failure, E.H.T. or H.T./L.T. failure, Valve drive or clutch failure (individual), Counter Scaler or Ratemeter failure, Broken wire or wire fray, CO_2 leakage or gamma activity in Gas Monitoring Room.

The precipitators, continuous and spare, have a common ring main on to which they can be valved, enabling a spare precipitator to be substituted for a faulty continuous precipitator, thereby reducing the loss of continuous scanning to a minimum.

Normal Operation

The only information normally displayed to the operator in the Control Room is the multi-point record of the duct gas activity (Rec D), unless the time corresponds with the log print-out time selector (23) (Fig. 3), when the typewriters will be printing out the channel group activities at the rate of 8 readings per $\frac{1}{2}$ minute per machine. However, the operator may choose additional information as follows:

1. Slave repetition of the individual scanning of each channel in a group carried out within the Gas Monitoring Room at his request.
2. Examination of the back 24 hours' history of any one group of channels during each scanning cycle. This is obtained by setting the desired precipitator and channel group numbers on selector switches situated on the front panel of the appropriate computer in the Control Room annexe. The back readings are then automatically identified and printed during the scan cycle when the 50-way valves coincide with the group selected (27) (Fig. 3).
3. The back reading typewriters may also be used to check the reference values for differential or absolute activity currently obtaining, with any group of channels. It is located by setting the precipitator and channel selector switches, when the information is immediately available by pressing the reference 'read' button to print out the set value on the typewriter.

If the operator requires to set in a new reference level, either differential or absolute, he sets up this value on 3 decade switches or alternatively dials it in, again selecting the precipitator and channel group and whether differential or absolute. Then by pressing the reference 'write' button, the new reference value is automatically substituted for the old.

Excess channel activity results in audible warning in the Control Room together with illumination of the major alarm indicating the computer involved. The relevant typewriter prints out the time, precipitator, and channel group, with the differential or absolute value. If the typewriter is already operating on a log print-out cycle then the log sheet continuity is interrupted by a change of format but there is no interference with the normal log print-out cycle timing.

The control engineer acting on alarm print-out information may request manual inspection of individual channels in the group affected and may then follow progress on the slave repeater recorder. He may also obtain the readings for the channel group over the past 24 hours together with a check of the reference levels set for the group.

The scaler units feeding the computer have been simplified to cover a single range of 0–10,000 counts per 30

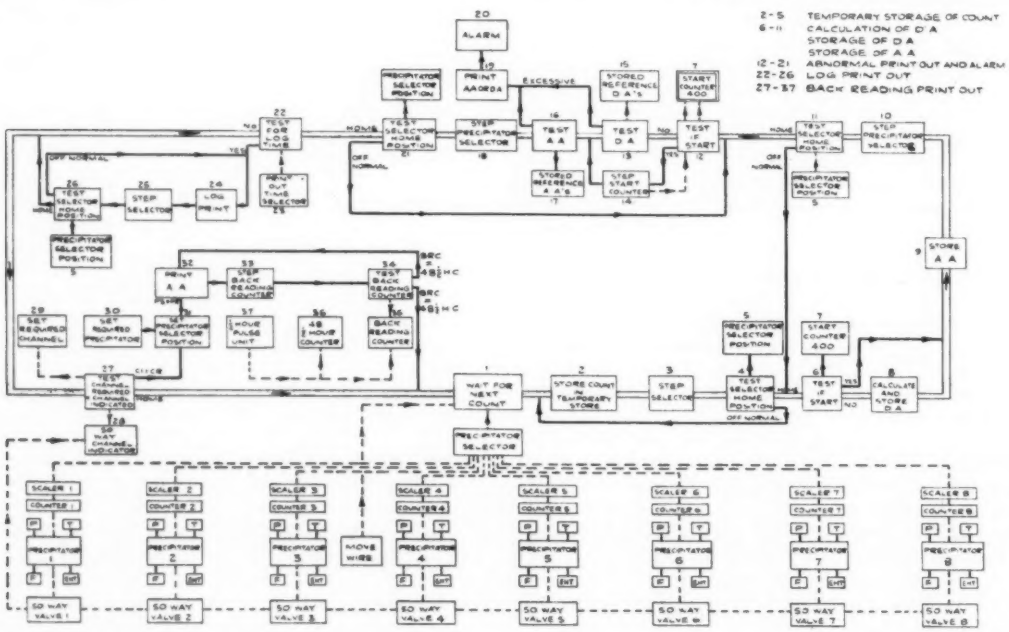


Fig 3 Block schematic diagram of an eight-precipitator unit shows working of system

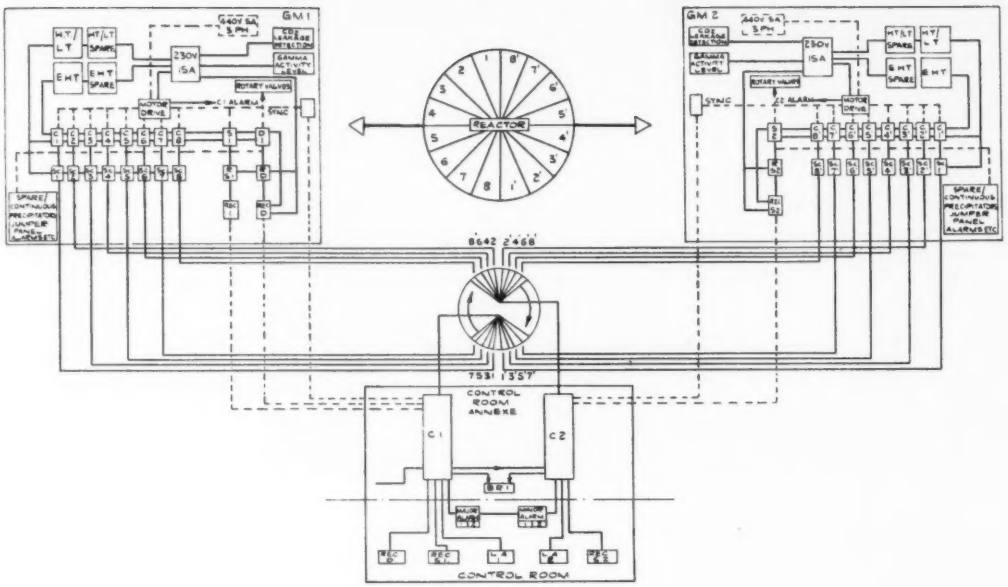


Fig 4 If one computer fails, the other can serve the whole reactor by electrical interlacing of the sectors

seconds. If a major split occurs the peak activity can be obtained on the switched range ratemeter used with each spare precipitator, and an assessment of the system contamination can be made on the duct activity recorder monitoring before the filter, again using a switched range ratemeter.

Equipment failure also causes an audible warning together with illumination of the major or minor alarm. The former covers the loss of circuitry covering an eight precipitator group, and is shown by the loss of 8 readings each half minute of the duration of fault. The latter covers the loss of circuitry covering one precipitator with the consequent loss of 1 reading each half minute of fault duration.

In the unlikely event of a complete failure extending over a few hours' duration, the whole reactor can be monitored once per hour for the duration of the breakdown. This is achieved by electrically interlacing the reactor sectors entering each computer (Fig. 4), necessitating the use of synchronous driving systems in each Gas Monitoring room.

Emergency working

Consider a breakdown in Computer 1 affecting the loss of 8 precipitators. Computer 2 is then left covering alternate segments of the reactor core 1.3.5.7.1'.3'.5'.7'. The group channel values in each of these sectors will continue to be monitored and compared with their respective preset AA's and DA's over the half-hour period. To cover the alternate segments of the failed computer, a rotary switch is operated half-hourly to connect the GM1 precipitators to Computer 2. Since the stored absolute and differential activities of Computer 1 are contained within its magnetic storage system, Computer 2 can only display the current activity readings as taken from the precipitator scalers. It is necessary therefore to switch the print-out time selector (23) (Fig. 3) to the hourly position coinciding with the failed computer segment scan period. An observer can then check the absolute channel activities from the Log/Alarm typewriter 2. After two complete print-outs it will be possible to make a visual assessment of the differentials as required by appropriate subtractions.

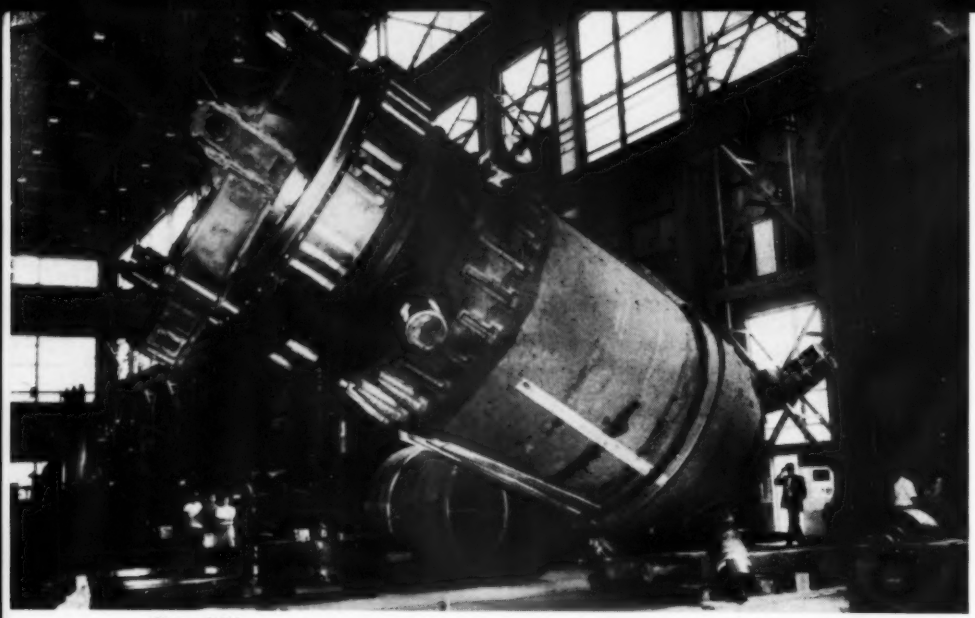
There are two fundamental requirements for the system: long term reliability, and ease of fault-location and remedial action. These are met by the following general specification:

1. Choice of magnetic storage drum speed—approximately 1/10th of that used in the average commercial computer, since this equipment must operate continuously.
2. Computer response frequency of approximately 1/10th of that used in the average commercial computer; this is possible since high electronic speeds are not called for to handle the counter information. Lowering the frequency of response in turn reduces the circuit and component optimum operating conditions.
3. Three basic circuit principles are employed,
   a. ON/OFF switching (binary scalers, etc)
   b. Saturating amplifiers (magnetizing circuits)
   c. Pattern generators (synchronizing circuits)

The circuits employ only transistors and germanium diodes, and the power supplies use selenium rectification. Transistors can operate satisfactorily with larger voltage swings than thermionic valves and, with stabilized power supplies, offer a maximum operational reliability. The wattage dissipation of a transistorized computer is roughly 1/20th of its hard valve counterpart, thus eliminating the temperature coefficient and ventillation problems associated with continuous operation.

Computer design readily meets the requirement for rapid fault location and diagnosis, since it is built up of a large number of units, most of which have common basic designs. Test signals can be routed through the computer on a scheduled basis, or manually as required, and progress followed till the faulty section has been located to a replaceable unit or sub-unit.

A miniature computer known as MINIGAME has been built by Sunvic Controls, Ltd, to give a practical simulation of the principal functions of the full scale equipment.



At the Chattanooga works, the 150-ton shell is ready for dispatch. Note support brackets below outlet branches

Photo: USIS

The PWR nec

pressure vess

LE VAISSEAU A PRESSION pour le réacteur à eau sous pression (PWR), qui est en train d'être construit à Shippingport, Pa, pour la Commission d'Energie Atomique aux Etats-Unis, entraîne des problèmes inusités de construction et fabrication. Les conditions de construction sont les suivantes : pression 170 atm abs ; température 316°C ; le couvercle doit être détachable afin de garantir l'accès à travers le diamètre entier. La cloche est faite en acier au manganèse et molybdène ayant une résistance à la traction minima de 5624 kg/cm² ; elle est revêtue au-dedans de l'acier inoxydable contenant 18% Cr et 8% Ni. L'épaisseur des extrémités hémisphériques est de 15,24 cm, celle des parties cylindriques est de 21,3 cm. Le couvercle est attaché à la cloche par 62 goujons de 15,24 cm de diamètre ; le poids de chaque goujon est 317,5 kg. Le poids total du vaisseau complet avec combustible et réfrigérant est de 391 tonnes.

DER DRUCKBEHALTER für den Druckwasser-Reaktor (PWR), welcher jetzt in Shippingport, Pa, für die Atomenergie-Kommission der Vereinigten Staaten gebaut wird, brachte mit sich ungewöhnliche Konstruktions- und Herstellungsprobleme. Die Konstruktionsbedingungen sind wie folgt : Druck 170 ata ; Temperatur 316°C ; der Deckel soll abnehmbar sein, damit der ganze Durchmesser zugänglich werde. Der Behälter wird as Manganmolybdänstahl (Minimalzugstärke 5624 kg/cm²) angefertigt und mit nichtrostendem Stahl (18% Cr — 8% Ni) innen ausgekleidet. Die halbkugelförmigen Endstücke sind 15,24 cm stark, und die zylindrischen Teile sind 21,3 cm stark. Der Deckel wird an den Behälter mittels 62 Bolzen von 15,24 cm Durchmesser und 317,5 kg Einzelgewicht befestigt. Das Gesamtgewicht des ganzen Behälters einschliesslich Brennstoff und Kühlmittel beträgt 391 t.

EL RECIPIENTE DE PRESION para el reactor de agua sobrecomprimido (PWR) que está siendo erigido actualmente en Shippingport, Pa, para la AEC de los Estados Unidos, presentaba problemas de diseño y construcción poco corrientes. Las condiciones del diseño son de 170 ata, 316°C, y el tope es demontable para facilitar el acceso al diámetro completo. El casco está fabricado de acero al manganeso-molibdeno con una resistencia mínima a la tracción de 5624 kg/cm², y se halla blindado interiormente con acero inoxidable de 18% Cr 8% Ni. Los extremos hemisféricos tienen un espesor de 15,24 cm y las partes cilíndricas de 21,3 cm. El tope está afianzado al casco por 62 pernos de 15,24 cm de diá con un peso de 317,5 kg cada uno. El peso total del recipiente completo, incluyendo el combustible y el enfriador, es de 391 toneladas.

НАПОРНЫЙ КОРПУС реактора с водой под давлением (PWR), строящегося теперь в Шиппингпорт, штат Пенсильвания, для Комиссии по Атомной Энергии США, порождает необычные проблемы в области как конструкции, так и стройки. Конструкция должна удовлетворять следующим условиям: давление 170 ата; температура 316°Ц; крышка должна быть съемная, чтобы обеспечить доступ на протяжении целого диаметра. Корпус построен из марганцевемолибденовой стали (минимальная прочность на растяжение 5624 кг/см²) и покрыта изнутри нержавеющей сталью 18% Cr—8% Ni. Толщина полусферических концов 15,24 см, а толщина цилиндрических частей 21,3 см. Крышка прикреплена к кожуху 62 болтами биаметром в 15,24 см и весом (каждый) в 317,5 кг. Общий вес всего корпуса с топливом и охладителем 391 т.

THE PRESSURE SHELL for the United States Atomic Energy Commission's 60MW pressurized water reactor was recently delivered to the site at Shippingport, Pa, and some details of its design and construction were released. Built at the Chattanooga works of Combustion Engineering Inc, the vessel is said to have been the most difficult job of its kind ever undertaken in the United States.

Preliminary details of the plant were given at Geneva (Paper 815). Briefly, there is a single core contained in a massive pressure vessel with four primary light water coolant loops—three of which are needed to produce the design output. Each loop supplies a steam generator which passes 287,000 lb/h to the turbine at 600 lb/in² abs, dry saturated.

The core consists of plate-type fuel elements containing enriched uranium with peripheral elements of natural uranium in tubes. The first core to be used is a right circular cylinder 6ft dia and 6ft high but it is anticipated that larger and higher-rated cores will be installed later. For this reason, the turbine installed will have a design output of 100MW. It will run at 1,800 rev/min. The high purity light water serves as both coolant and moderator and is circulated at a pressure of 2,000 lb/in² at 4,500 gal/min by canned-rotor pumps.

The water enters the shell through branches at the bottom. Inside, most of the flow takes place through the core, but a proportion is by-passed to provide thermal shield cooling. At the top, the water is removed through four nozzles and passes to the heat exchangers. Pressure in the vessel is maintained constant by an electrically-heated pressurizing tank.

With the thicknesses of plate and forgings visualized, accepted methods of stress analysis were of little help. In addition to pressure and thermal stresses due to transient conditions account had to be taken of thermal stresses arising from capture gammas. As a result of experience gained in constructing the vessel, it is anticipated that new design criteria established will be of value in similar large components for nuclear plant.

The design conditions for the vessel were 2,500 lb/in² 600°F. It consists of two portions, a flanged cylindrical shell with a hemispherical bottom dome and an upper flanged dome bolted to the lower and removable to give full-way access to the shell. The internal diameter of the shell is 9ft in and it is about 33ft high outside.

The cylindrical portion, which is 8⅜in. thick, is formed in two courses, each of which is made from two semi-

nears completion

vessel at Shippingport

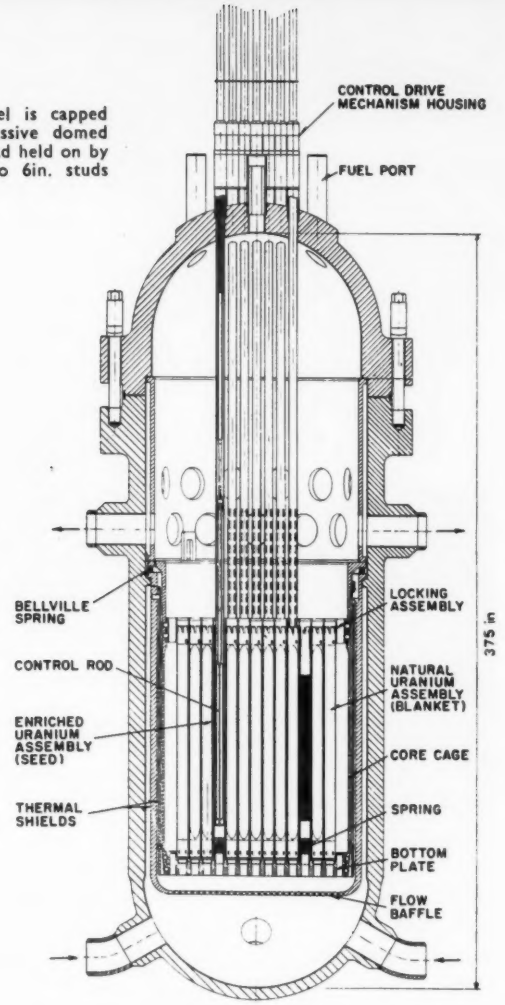
cylindrical pressings. There are thus three circumferential and two longitudinal welds. The top and bottom domes are forgings, the former being 10in. thick and increased at points where the control rod mechanisms and fuel loading ports are located. The lower dome is 6in. thick. The bolt flanges on both shell and upper dome are forgings 24in. square in cross section and drilled with sixty-two holes for the holding-down bolts.

The material used in the vessel is manganese-molybdenum steel to ASME Material Specification SA-302, Grade B, which calls for a minimum ultimate tensile strength of 80,000 lb/in². The specified composition is: manganese—1·10 to 1·50 per cent. molybdenum—0·40 to 0·60 per cent. carbon—0·27 per cent max. The manufacturers, the Lukens Steel Co, have however achieved the minimum tensile properties with carbon less than 0·25 per cent. To obviate any possible risk of corrosion the vessel is completely clad internally with ¼in. of stainless steel to AISI Type 304-L (18 per cent chromium, 8 per cent nickel, carbon not exceeding 0·03 per cent.). In the cylindrical portion and the bottom dome the cladding is integrally rolled on to the plate before forming to shape, but for the flanges and the very thick top dome this was not possible and a special method was developed for cladding the metal by weld deposition after fabrication. The bond between the cladding and the base metal had to meet the shear test requirements of ASME Specification SA-264 and the continuity of the bond was examined over 100 per cent of the clad surface by ultrasonic inspection. This method was also used to check the base metal for inclusions.

The head is held to the shell by 62 6in. dia studs, 80½in. long. Each stud with its nut weighs 700lb. Under design conditions, the force in each stud required to maintain contact between the mating surfaces is 40,000 lb. In order to produce this load, the studs incorporate built-in electric heating elements so that the required degree of pretension can be applied.

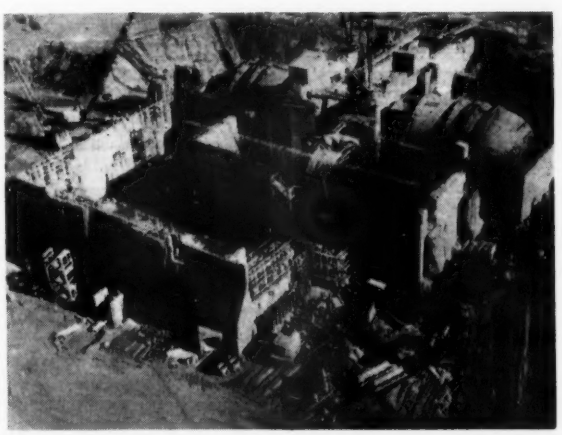
The four outlet nozzles are located 60° and 120° apart just below the vessel flange: the inlet braches are 90° apart and enter the bottom dome normally. These nozzles are made in 6in. plate rolled into cylinders and welded in. The removable head has 46 openings in which are fitted facilities for control rods, fuel charging and discharging gear, instrument leads and so on. The complete vessel with fuel and coolant in place will weigh about 385 tons and will be supported by 24 brackets placed three feet below the centreline of the outlet branches.

The vessel is capped by a massive domed head held on by sixty-two 6in. studs



Since the distance from the openings to the core is about 18ft, to ensure proper functioning of the control rods and the charge/discharge mechanism the overal alignment tolerance is 0·011 in. per foot.

The PWR is due for operations later this year.



Each of the two cylindrical shells contains two steam-raising loops, the reactor vessel being between them.

On the next six pages we give a brief preview of some of the instruments which will be on show. We have selected those which we think will be most interesting to our readers, and for which information was available at the time of going to press

PHYSICAL SOCIETY EXHIBITION MARCH 25 to 28

The exhibition will be held in the Old and New Halls of the Royal Horticultural Society, Westminster, from Monday, March 25 to Thursday, March 28. It will be opened on March 25 at 11 am by Professor P. M. S. Blackett, FRS, Professor of Physics at Imperial College of Science and Technology.

The Exhibition will be open during the following hours:
Monday March 25 10.30 am to 7 pm (Fellows and Press only, 10.30 am to 2 pm)
Tuesday March 26 10 am to 9 pm
Wednesday March 27 10 am to 7 pm
Thursday March 28 10 am to 4.30 pm

Tickets may be obtained free of charge from the Society at 1 Lowther Gardens, Prince Consort Road, London SW7. Applicants are asked to enclose a stamped addressed envelope. Visitors' tickets give admission on any of the four days.

ACCLES & POLLOCK LTD **STAND 54**

Tubing The exhibits will include tubes in tantalum, beryllium, vanadium, molybdenum, niobium zirconium, zircaloy II and titanium. There will also be samples of seamless, stainless, flexible tubing, flexible joints, annular convoluted tubes, and helically finned steel tubing usually used as heat exchangers. Special thin-walled stainless steel tubing with 0·005in. to 4¼in. dia. will be shown.

AUTOMATIC COIL WINDER AND ELECTRICAL EQUIPMENT CO LTD **STAND 42**

Avo portable d.c. amplifier, Produced in conjunction with AERE, this highly stable instrument operates with an ionization chamber conforming to the requirements of the NPL Advisory Committee on radioactive standards. It has seven input ranges, measuring 10^{-6}–10^{-12} amp at full scale sensitivity of 10V, and 3×10^{-7}–3×10^{-13} amp at 3V sensitivity. The accuracy is ±3% at full scale deflection, and the output for recorder operation is 100MV.

Portable radiation monitor Also designed in conjunction with AERE, this measures beta and gamma radiation within the range 2mr/h to 5r/h. Also on show will be Mks 2 and 3 of the *Radiac* survey meter.

BAIRD AND TATLOCK LTD **STAND 116**

Analmatic Uranium Analyser, Mk II The analyser is used for rapid chemical analysis of effluents from ion exchange columns in uranium liquid flow lines. It will perform continuous analysis without attention, monitoring up to sixteen process streams.

Analmatic Auto-Titrator A further development in the *Analmatic* range, desiged for partial automation, this instrument records measurements requiring a titration where potentiometric or pH end-point is applicable.

BALDWIN INSTRUMENT CO LTD **STAND 98**

Nucleonic level indicator By fitting a radioactive source on one side of a container and a detector on the other, the level of the contents can be indicated or controlled without any fitting inside the container. When the material inside the container cuts the radioactive beam, the radiation strength reaching the detector is reduced, and the detector is arranged to discriminate between the two different insensities of radiation.

Also on show will be some units of the well known range of *Atomat* gauges, including the beta ray thickness gauge, the transverse profiler, and nucleonic thickness gauge.

BRITISH PHYSICAL LABORATORIES **STAND 106**

Valve voltmeter (model VM 348-6) This new instrument is a development of the VM 348. The frequency band has been extended to cover 40 c/s to 10 mc/s, with a maximum sensitivity of 2mV at full scale deflection. The size has been reduced, and the scale is now marked in both millivolts and decibels.

BRITISH THOMSON-HOUSTON **STAND 12**

Transistorized vibration measuring equipment This battery operated equipment, which will be demonstrated working in conjunction with a velocity type vibration pick-up, measures the velocity, amplitude and frequency of vibrations in the range 5 to 100 c/s. The waveform is displayed on a cathode ray tube.

Prolonged flashes in zenon The equipment to be demonstrated shows how, by controlling the rate of discharge of energy in a xenon flash tube, the single flash rating can be increased by a factor of at least six times for a light gain of five times.

The most recent developments in semiconductor devices and some working models will also be shown.

BURNDEPT LTD **STAND 8**

Fast neutron monitor (type 1407C) This monitor, developed for AERE, Harwell, makes use of a proton recoil counter. Three count ranges are provided, 0–4, 0–40 and 0–400. The instrument is sealed into a 16in. by 10in. by 6in. case, the necessary batteries also being contained in the case.

Transistorized geiger counter (type BN 113) In spite of its small size, this portable survey meter uses a full size geiger tube. The transistors are temperature compensated, and the circuit used is to an approved Harwell specification. Leclanché or mercury cells provide the power. The count is registered on a metre with two ranges, and headphones are also provided.

CAMBRIDGE INSTRUMENT CO LTD **STAND 41**

New coding system for segmental measurement In this system, scanned points are encoded by a method which makes use of both the horizontal pen movement and vertical chart movement of a recorder. The resulting code appears in the form of blips, and the system may be applied to 99 or more individual points, *e.g.* the recording of multiple temperatures.

CASELLA (ELECTRONICS) LTD **STAND 88**

Automatic particle counter and sizer This instrument uses the principle of anode track scanning and variable sensitivity. For easy operation, the slit mechanism, microscope unit and electronics are contained in a console cabinet. Four sensitivity channels can be added to the single one of the simple form, reducing the analysis time by a factor between 3 and 4.

A production version of the gas liquid chromatography apparatus, shown as a prototype in 1954, is now available. The adoption of coiled metal tube columns, packed with a relatively coarse fraction of *Celite*, enables the instrument to be rearranged into two short units instead of one long one.

CHANCE BROS LTD **STAND 102**

Protective glass Blocks and sheets of glass for protective windows will be exhibited on this stand. Windows of lead glass, density 4·3 g/cm^3, are made up to 18in. square and of requisite thickness, and blocks of smaller area are made in glass of density 6·1. Polished plate glass 1 in. thick, with densities 2·5 or 4·3, is used for windows up to 10 ft^2 in area.

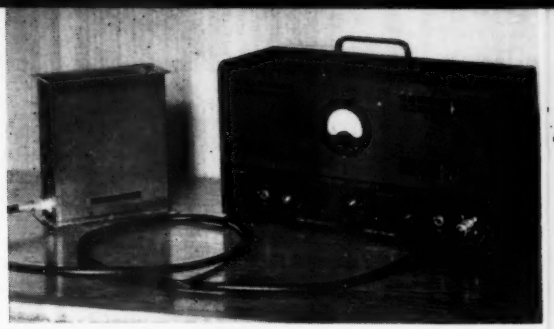
Also displayed will be Cherenkov blocks of high transmission lead glass for gamma ray spectroscopy by the method proposed by Kantz and Hofstädter. An incident gamma ray or electron develops a soft shower in the glass, and the incident energy is almost entirely dissipated in relativistic electron tracks which radiate a constant quantity of Cherenkov light per unit length. The glass is viewed by a photomultiplier which gives a pulse proportional to the electromagnetic energy incident on the glass.

DAWE INSTRUMENTS LTD **STAND 38**

Ultrasonic cleaning equipment (type 413) A production model of the equipment shown at last year's exhibition is now available. Among its uses is the cleaning of radioactive soils, and also of fine instruments.

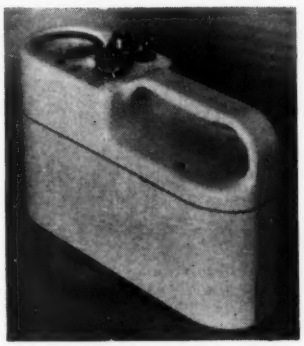
Cleaning occurs as the result of the rapid formation and collapse of vapour bubbles in a corrosive liquid which is excited ultrasonically. Thus many assemblies otherwise difficult or impossible to clean may be treated.

Cylindrical tank transducers of a half or one gallon capacity are available, with barium titinate elements built into the base. Alternatively there are immersible units for use with existing baths. All assemblies are of stainless steel, and highly corrosive liquids may be used by placing them within an inner plastic or glass container.



DAWE—ultrasonic cleaning apparatus

BALDWIN—nucleonic level indicator



BURNDEPT—transistorized geiger counter

BTH—vibration measuring equipment

AVO—Radiac survey meter

CASELLA—automatic particle counter and sizer

DYNATRON RADIO LTD **STAND 29**

Single channel scanning pulse amplitude analyser This analyser has a channel width adjustable from 0–10V to 0–50V and accepts pulses in the range 5V to 110V, transmitting those pulses with amplitudes within selected levels. The transmitted pulses are converted to output pulses and may be fed to either a scaling unit or ratemeter.

Transistor operated portable scaling unit (type 1287A) This portable five decade scaler is designed for arduous use in the field. The addition of a suitable g-m tube makes this equipment suitable for the measurement of radioactivity in geological surveys, mining and many other applications.

EDWARDS HIGH VACUUM LTD **STAND 112**

Pumping combinations suitable for nuclear activities Fractionating diffusion pumps of advanced design will be shown equipped with guard rings to control backstreaming, refrigerable chevron baffles to reduce the pumping fluid vapour pressure above the baffles to a negligible magnitude and automatically operable valves to seal against atmospheric pressure in either direction.

Fractionating diffusion pump This large four-stage pump, of 24in. diameter, is planned for production. It has a backstreaming control device, and is suitable for exacting duties on nuclear machines.

Low pressure ionization gauge Planned for production, this gauge is for measurement below 10^{-8}mm Hg for which the electron current due to the X-ray effect must be minimized.

Arc melting furnace This experimental, laboratory equipment has a water cooled hearth, by which very high temperatures may be obtained and contamination from refractory containers avoided. A special feature is the ease of conversion for melting with consumable or non-consumable electrodes.

A range of vacuum instrumentation will also be shown.

ELLIOTT BROTHERS LTD **STAND 108**

Analogue computer This general purpose d.c. instrument will be shown by the computing division solving various linear and non-linear problems, including the study of the power levels in a nuclear reactor, the simulation of a servo system with backlash present, and the solution of a partial differential equation describing the vibration of a cantilever.

Ionization gauges The research division will be showing two ionization gauges: a broad type cold-cathode gauge for use in the range 10^{-2} to 10^{-7}mm Hg; and a hot-cathode type, constructed to minimize errors due to X-ray generation.

The division will also exhibit a simple megatron for detecting the presence of ions of a particular mass. It can be used for leak detection as an alternative to the mass spectrometer type of detector.

EMI ELECTRONICS LTD **STAND 22**

Two **d.c. measuring oscilloscopes** for use in fast pulse and wide bandwidth applications will be shown, capable of measuring time intervals and a.c. and/or d.c. signals with accuracies of 2½%. The new **pulse generator** type 2 to be shown produces pulse widths from ·05 microseconds to 1 microsecond under single shot or high repetition rate conditions.

For the accurate generation of pulses at pre-determined time intervals the precision **digital delay generator** which will be exhibited may be operated under recurrent or single shot conditions. Repetition and delay periods may be varied over the range 1 μs to 100 ms.

FERRANTI LTD **STAND 31**

Magnetic drum storage unit The unit contains a magnetic drum store and circuits for address selection, reading and writing complete with all necessary power supplies. The rotational speed of the drum may be chosen within the limits of 1,000 and 4,000 and circuits are included for phase synchronization at any chosen speed within these limits. The storage capacity is divided into 128 tracks and is equivalent to a 300ft reel of magnetic tape. Switching between the tracks is accomplished through germanium diodes in a time less than 10 microseconds. The maximum pulse repetition rate is 250 kc/s and the maximum bit density 200 per in.

FLEMING RADIO (DEVELOPMENTS) LTD **STAND 44**

Radioactive dust sampling equipment The group of equipment to be shown, developed in collaboration with AERE, forms a universal dust and contamination sampling equipment. It comprises five units: a dust sampler, basically a household suction-cleaner with a special nosepiece containing a filter-paper holder and an anemometer; a universal sealer/ratemeter; a beta/gamma probe for general contamination monitoring; a 'castle' unit for measuring beta activity collected on filter paper or for general beta sample measurements; an alpha probe for bench monitoring, which can be used as a sample-counter in conjunction with a drawer-assembly.

Logarithmic ratemeter This consists of a linear dialled diode pump feeding into a crystal diode which converts the mean rate of arrival of the pulses into a d.c.-potential. This is fed into a logarithmic amplifier, and the output displayed on a 4in. *Cirscale* instrument calibrated 5–5 × 10^5 c/s in decades. The activity meter comprises a differentiating circuit giving an output proportional to the rate of change of output from the logarithmic ratemeter. Trip circuits are fitted on both the activity meter and the ratemeter.

GENERAL ELECTRIC COMPANY LTD **STAND 24**

A new range of hydrogen thyratons will be shown incorporating the new barretter-controlled hydrogen-replenisher system. Particular features are the economy of filament power and the relatively small physical size for the high power output.

Three new cathode-ray tubes will be exhibited: a multiplication tube with an application to analogue computers, a frequency-multiplier tube, and a computer storage tube.

There will also be a comprehensive range of silicon and germanium semi-conductor devices, including germanium and silicon diodes, ranging from small signal diodes with reverse impedances of several hundred megohms, to diodes giving tens of amperes from a bridge network.

GEC RESEARCH LABORATORIES **STAND 25**

The semiconductor display will include a large single crystal of germanium weighing over 1kg, and a single crystal of silicon. Some interesting applications will be demonstrated.

There will also be a demonstration of the quantiative determination of the composition of rare gases by electrophoretic separation. The length of the cathode discharge in a tube containing a mixture of two gases is related to the concentration of each. When the total gas pressure is a few millimetres, proportions in the range 1 part in 10,000 to 1 part in 50 can be estimated.

GRIFFIN & GEORGE LTD **STAND 40**

Courtauld Atomic Models The arrangement of brass link and rubber collar by which the models are joined together

GRIFFIN & GEORGE LTD **STAND 40**

Courtauld Atomic Models The arrangement of brass link and rubber collar by which the models are joined together provides elastically-distortable valency angles. The length of the link used ensures that the structures are sufficiently open to allow easy visual inspection. In particular, bond directions may be readily observed. However, there is no sacrifice of free rotation about single bonds and the link is strong enough to allow the largest molecules to be handled without falling apart.

Mk II of the VPC gas-liquid chromatograph, described in Nuclear Power, March 1956, p 70, will be shown.

GRUBB, PARSONS & CO LTD, SIR HOWARD **STAND 71**

A number of instruments will be demonstrated on this stand. They include: A prototype self-balancing infra-red gas analyser incorporating a single infra-red source totally enclosed, electrical or pneumatic output for operating remote recorders or controllers, and vibration immunity.

HILGER & WATTS LTD **STAND 109**

Among the exhibits will be: A prototype atomic-absorption attachment for the *Unispek* spectrophotometer. Sample solution is sprayed from an atomizer onto a flame through which passes the light of a hollow-cathode lamp emitting the characteristic radiation to be measured; a redesigned version of the microfocus X-ray generator; and experimental photoelectric modification of the standard Hilger visual polarimeter in which visual fatigue is almost entirely eliminated; mechanical and shaft rotation digitizers, giving remote indication of the angular rotation of a shaft in numerical display; typewritten or punched form; scratch-investigation microscope and camera capable of measuring scratch depths of 0·0005 to 0·01 in.

ISOTOPE DEVELOPMENTS LTD **STAND 6A**

Ionization chamber (type 1506 B) This large gamma ionization chamber, developed in collaboration with AERE, has 'airwall' characteristics for general purpose health monitoring. It operates at atmospheric pressure and delivers 6×10^{12} amp at a dose rate of 10 mr/h.

Gamma reflexion gauge (type 190) This gauge covers thickness measurement in the range 200 mg/cm² to 2,000 mg/cm² with an accuracy of $\pm 1\%$. The dependence of the gauge on strip position relative to the unit is negligible within $\pm\frac{1}{2}$in. It incorporates novel collimation, self-calibration and radiation protection features.

Also demonstrated will be a fast response beta gauge, an experimental profile gauge and a single channel pulse analyser with automatic scanning unit.

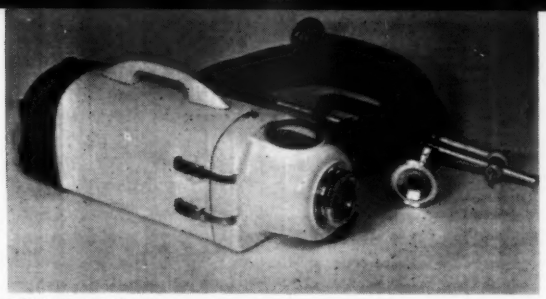
JOYCE, LOEBL & CO LTD **STAND 60**

A direct-beam precision condensation nucleus counter will be shown for the first time. The association of this company with Optica Milano in the manufacture of UV Spectrophotometers is shown in the CF4 instrument, which is now being made in this country, and which it is hoped to show.

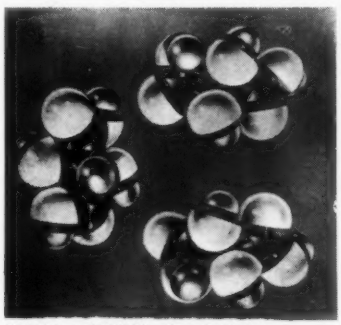
MEGATRON LTD **STAND 49**

Selenium photo cells A range of different sizes and shapes of mounted and unmounted selenium photocells with different spectral characteristics will be shown, including, for the first time, 'potted' selenium cells with soldered electrodes cast air tight into araldite (patent pending).

Electrically conductive glass Three different types of conductive glass will be shown which can be used as antistatic windows on instruments and as de-misting and defrosting panels.

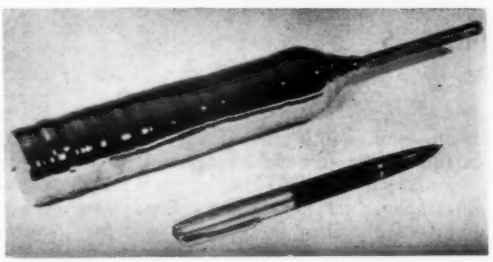


FLEMING RADIO—Dust sampler

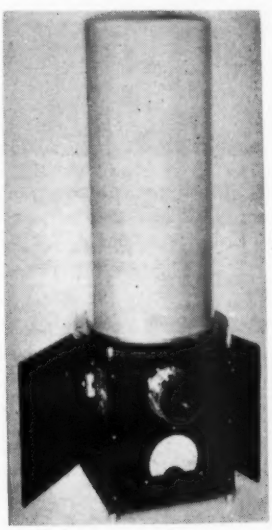


GRIFFIN & GEORGE—Atomic Models

FERRANTI—Junction diode



GEC RESEARCH LABS—Germanium single crystal



ISOTOPE DEVELOPMENTS —Airwall ion chamber

MUREX LTD **STAND 35**

Fabrication of refractory metals Niobium sheet, rod and drawn tube, now available for industry, will be among the exhibits. Beryllium metal sheet and beryllia crucibles and thermocouple sheaths, a metal with low nuclear absorption cross section, will be shown by courtesy of the AEA.

The *Sincomax* range of permanent magnets now includes the multi-section 'sandwich' type of assembly in which various sections of permanent magnet alloy alternate with soft iron sections. The mechanical strength of these magnets, due to fine crystal structure, makes them suitable for application in parts rotating at high speed.

NEWPORT INSTRUMENTS LTD **STAND 43**

Magnetometer (type G) This laboratory instrument measures fields in the range 0·1 to 1,000 oersted. Determination of the gyromagnetic coupling in a ferrite sample gives a direct, continuous indication of the field value. A small toroid of *Ferrox-cube*, mounted on a probe, is magnetized by an a.c. field derived from a stable oscillator. The second harmonic output from a pick-up coil wound on the sample is fed to a 4in. circular scale meter, calibrated directly in oersteds.

Power supply (type A) This is an a.c. operated d.c. supply for electromagnets, designed to give a highly stable source of current for nuclear resonance work. The unit will deliver up to 20 amp, d.c. voltages up to 120V to suit the majority of optimum design magnet coils. It contains no thermionic valves, and is designed to have as great a reliability as the magnet coils themselves.

PYE & CO LTD, W. G. **STAND 75**

A wide range of instruments will be exhibited including: a liquid density indicator, for continuous recording and control of liquid densities in industrial plant. The displacement of a hygrometer float is detected by a pick-up head, and the proportional electrical symbol produced, suitably amplified, operates a recorder or controller.

PANAX EQUIPMENT LTD **STAND 64**

Automatic counting equipment (type AC 300/5) This is a fully automatic counting system for use with geiger or scintillation counters incorporating a stabilized e.h.t. supply, preamplifier and discriminator. Facilities are provided both for timing against preset count and for counting against preset time.

Scintillation counter Compact and flexible, this instrument is for counting both liquid and solid samples. A 1½ in. thallium activated sodium iodide crystal is used, mounted in a hermetically sealed container.

Portable monitors (types TR 556 and TR 33) These transistor operated instruments, shown in development form last year have been much improved and the production versions are now available. The instruments are of pocket size and weigh only 3lb. The TR 33 gives audible indication only from a built-in speaker and the TR 56 gives meter indication of the dose rate with two ranges 0-0.5 and 0-5 mr/h. This instrument can also be supplied with ranges more suitable for health monitoring.

SALFORD ELECTRICAL INSTRUMENTS LTD **STAND 16**

Torque-balance unit Used mainly for the remote indication of electrical quantities and in electrical or electronic telemetering systems, this instrument consists basically of two electrical movements connected so that their torques oppose on a common spindle.

Developments in displacement transducers will be shown, including the use of an indicator with adjustable contacts for on/off control, and a rectifier conversion unit enabling moving coil indicators and recorders to be used with any type of transducer.

SERVOMEX CONTROLS LTD **STAND 51**

Low frequency waveform generator (type LF 51) This instrument generates a wide variety of electrical test signals, including sine waves from 0·0005 to 500 c/s, square waves and pulses of 100 μs to 1,000 sec duration, ramp functions, triangular, sawtooth, trapezoidal and cosine-shaped pulses. In addition to continuous operation, it can generate a half cycle or one complete cycle. It can be used in programming automatic systems and in analogue computation.

SIEMENS-EDISON SWAN RESEARCH LABORATORIES **STAND 37**

Personal gamma radiation monitor Worn in the pocket this instrument is designed for use in situations where it would not be possible to examine the quartz fibre dosimeter. It gives an audible warning when it has received an integrated dose of 0·1V.

P-n-p function transistor bridge This experimental laboratory test set features a rapid check of the transistor parameters after initial setting up by switching it in turn to four independent bridges. This ensures that a consistent set of parameters is measured at one d.c. working point and one temperature.

SOLUS-SCHALL LTD **STAND 30**

Fast neutron scintillation counter This portable instrument is designed to detect fast neutrons in the energy range 0·1–20 MeV, an efficiency of 0·7% being obtained with a Ra-Be source. The phosphor is in the form of a sphere, and good gamma discrimination is obtained by limiting the thickness. Cold cathode circuiting is used throughout, powered by a Ag-Zn lightweight accumulator (General Radiological Ltd)

Ultrasonic flaw detector This employs a frequency pulse echo vibration technique registering on an oscillograph screen. It is used for the non-destructive examination of machined parts, forgings, welded joints, and the determination of wall thickness.

Waveform Generator (type 1405 A) The output waveform may be either a square wave of approximately 1/1 mark/space ratio with one fast edge and the other deliberately slow for outputs of 0–1V, or regularly spaced rectangular pulses for 0–1V and 0–50V outputs.

SOUTHERN INSTRUMENTS LTD **STAND 92**

Sindak data-reduction equipment The *Sindak* range of equipment is being built up by the computer division to cover all the requirements of records analysis. On show will be the K1015 Trace Reader which is semi-automatic in operation, relying only on the positioning of a cursor on the point required, and the pressing of a foot switch to give the value of the trace amplitude at that point, typed out. Some thousand points on the trace can be taken per hour, strip charts up to a width of six inches being accommodated.

Another system will also be shown which uses a similar cursor method and provides extra features such as the insertion of linear and non-linear scale factors, enabling the final output to be obtained in the limits of the original trace. The digital output may be presented either on a typewriter or visually. A tape perforator may also be actuated where processing of the data by a digital computer is required.

STANDARD TELEPHONES AND CABLES LTD **STAND 10**

Transistorized ferrite store The exhibit comprises a magnetic cell store whose reading and writing access waveforms are derived from novel transistor circuits. The output signals are amplified by transistor pulse amplifiers and fed into a simple transistorized logical circuit. It demonstrates the magnetic cell principle, *i.e.* the substitu-

STANDARD TELEPHONES AND CABLES LTD—continued

tion of a drilled ferrite block for individual ferrite cores, and its special suitability for working in conjunction with transistors.

SUNVIC CONTROLS LTD **STAND 82**

Pneumatic-electric transducer The prototype unit to be displayed converts air pressure signals in the range 3 to 15 lb/in^2 into a proportional d.c. output current in the range 0 to 10mA. A force generated pneumatically is balanced against one generated electromagnetically by means of a moving coil and permanent magnet assembly. The balance point of the instrument is detected by means of a differential transformer.

Pneumatic multiplying relay A prototype design will be exhibited capable of delivering a signal proportional to: the product of two independent signals, the square of a single output, the quotient of two independent input signals, and the square root of a single input signal. It works on the force balance principle.

TINSLEY & CO LTD, H. **STAND 99**

This firm has specialized in the miniaturization of laboratory instruments. New techniques have enabled precision instruments to be reduced to a quarter or less of their former size without any loss of accuracy, and a more even distribution of temperature may improve the accuracy. Examples of the range to be shown are a two-dial precision potentiometer (type 4025-C), especially designed for thermocouple work, and a vernier potentiometer (type 4363-F). This incorporates a five-dial current regulator and three pairs of potential measuring connections.

DC amplifier A galvanometer-photoelectric cell combination, thyratron amplification and negative voltage feedback are used in this instrument to give amplification of small direct voltages. It operates entirely from 250v 50 c/s mains and several alternative input characteristics may be provided.

WAYNE-KERR LABORATORIES LTD **STAND 79**

Transformer bridges applied to chemical measurements The demonstration will show the use of the transformer ratio-arm bridge to measure the conductivity of liquids without the use of electrodes. Both comparative and absolute values of conductivity within the range 10^{-1} to 10^{-9} mhos/cm are possible. Conductivity measurements of a liquid flowing in a pipe will be shown and also the wide range of dielectric constant measurements possible using this type of bridge. The method will be demonstrated at audio frequencies with both solid and liquid dielectrics.

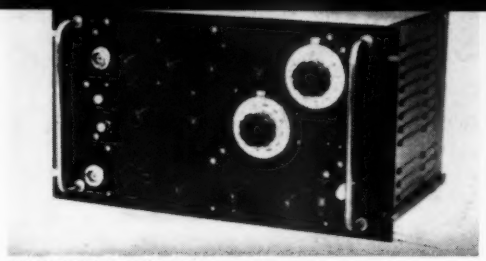
WESTINGHOUSE BRAKE & SIGNAL CO LTD **STAND 21**

Dynamic test equipment for semiconductor diodes The dynamic test equipment to be demonstrated enables the forward and reverse dynamic performance of semi-conductor diodes to be measured independently while under full load without introducing any spurious modulation effects or errors.

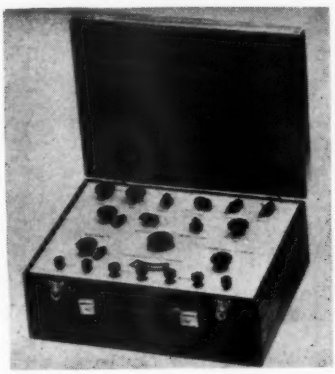
Copper oxide rectifiers New process rectifiers will be shown in which the maximum a.c. input voltage has been increased from 8 to 25V rms per element, and reverse current creep has been virtually eliminated.

Miniature selenium diode This new current diode (type 310EAI) has a very high reverse impedance. A typical value is 300 M ohm at 60 V at 25°C.

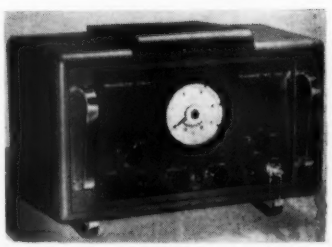
Also shown will be edge-cooled, sealed rectifier units to operate at high and at medium temperatures. They employ a new cooling principle in which heat is removed by conduction from three of the edges of each square element, the fourth being left free from connexions.



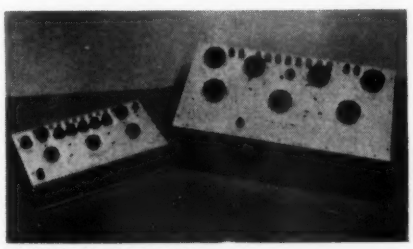
SOLUS-SCHALL—Waveform generator



PYE—Thermocouple test set

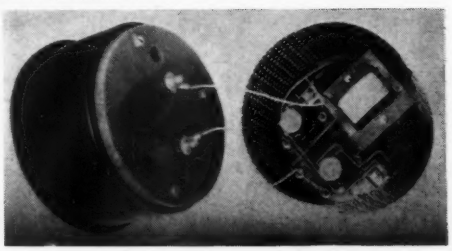


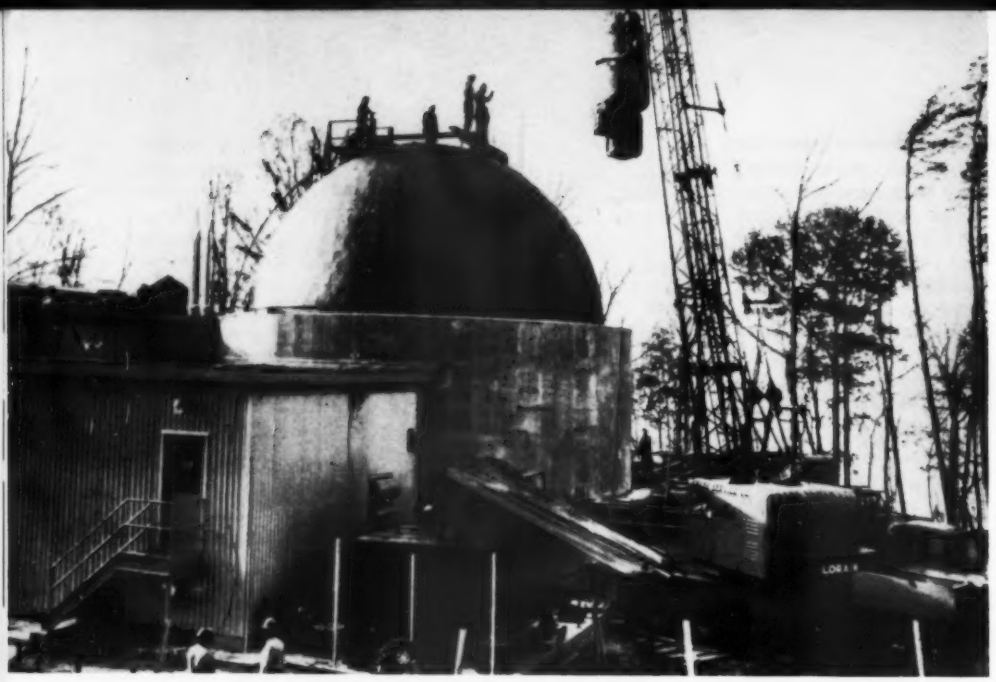
NEWPORT INSTRUMENTS—Magnetometer



TINSLEY—Vernier potenticmeters

SALFORD—Rectifier conversion set





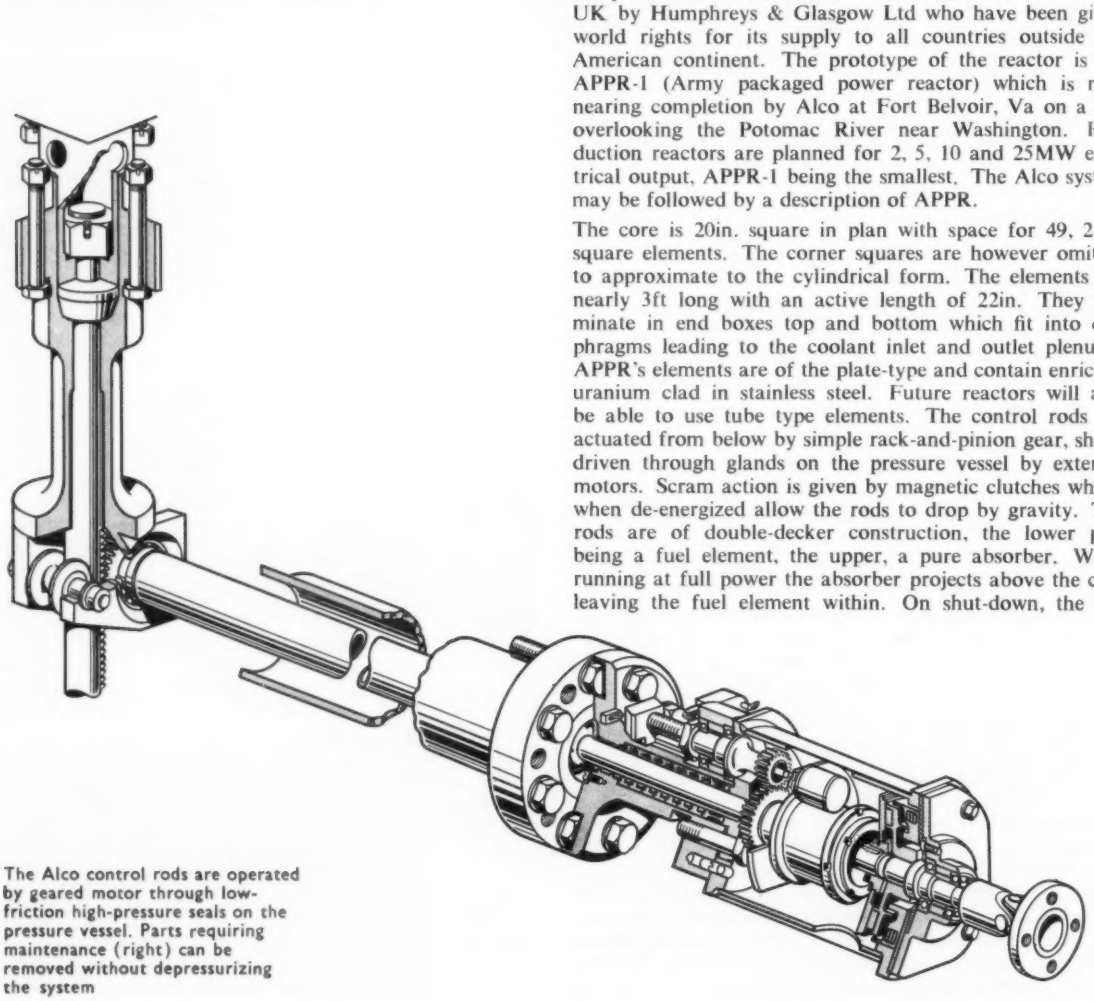
Now nearing completion near Washington, the reactor pressure vessel is lowered into the steel-and-concrete vapour container of the US Army's APPR-1 plant

Packaged P

British firm's agr

AS ANNOUNCED LAST MONTH, the Alco Products Inc pressurized water reactor is to be manufactured in the UK by Humphreys & Glasgow Ltd who have been given world rights for its supply to all countries outside the American continent. The prototype of the reactor is the APPR-1 (Army packaged power reactor) which is now nearing completion by Alco at Fort Belvoir, Va on a site overlooking the Potomac River near Washington. Production reactors are planned for 2, 5, 10 and 25MW electrical output, APPR-1 being the smallest. The Alco system may be followed by a description of APPR.

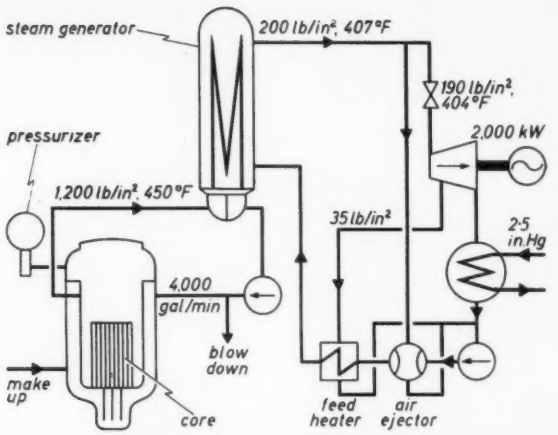
The core is 20in. square in plan with space for 49, 2¼in. square elements. The corner squares are however omitted to approximate to the cylindrical form. The elements are nearly 3ft long with an active length of 22in. They terminate in end boxes top and bottom which fit into diaphragms leading to the coolant inlet and outlet plenums. APPR's elements are of the plate-type and contain enriched uranium clad in stainless steel. Future reactors will also be able to use tube type elements. The control rods are actuated from below by simple rack-and-pinion gear, shaft-driven through glands on the pressure vessel by external motors. Scram action is given by magnetic clutches which, when de-energized allow the rods to drop by gravity. The rods are of double-decker construction, the lower part being a fuel element, the upper, a pure absorber. When running at full power the absorber projects above the core leaving the fuel element within. On shut-down, the rod



The Alco control rods are operated by geared motor through low-friction high-pressure seals on the pressure vessel. Parts requiring maintenance (right) can be removed without depressurizing the system

PWRs to be built in UK

agreement with US company

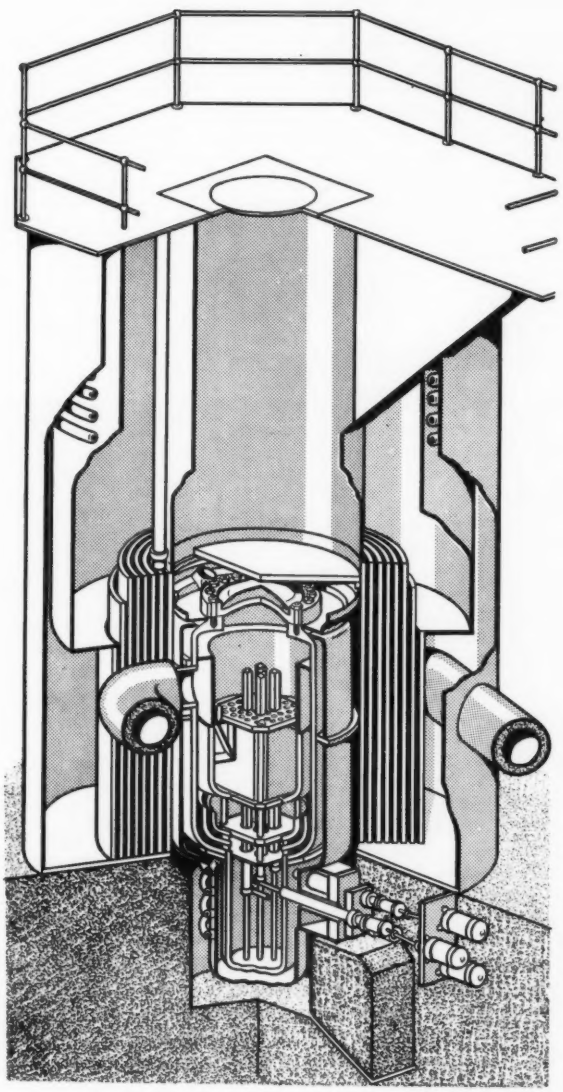


Simplified flow sheet shows main features of pressurized water system. Actual figures refer to APPR-1 plant

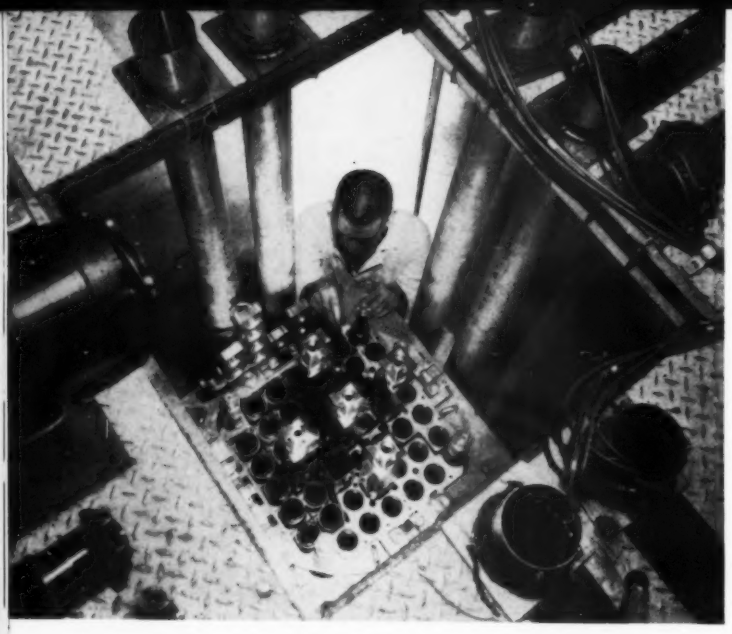
descends, thus removing an element and introducing a neutron absorber.

The core is contained in a pressure shell 4ft diameter and about 13ft high. Surrounding the core inside the vessel is a concentric thermal shield and the primary cooling water is led in through the pressure shell to the annulus formed by it and the shield. From here it flows downward to the inlet plenum, up through the core and out through the outlet pipe which lies in the same plane as the inlet but which penetrates through the shield. On leaving the reactor, the hot water (450°F, 1,200 lb/in²) is fed to the steam generator. This is a vertical shell containing two sets of hairpin tubes—one an evaporator section, the other a superheater in which the secondary water is given a mild superheat (25°F). Circulation of primary water is by canned rotor pump and pressure is maintained by an electrically-heated pressurizing tank automatically controlled. APPR-1 has a 2,000kW turbine taking steam at 194 lb/in²a, 404°F, the steam circuit being largely conventional.

The pressure vessel is closed at the top by a bolted plate and the whole is surmounted by a cylindrical tank 9ft deep, containing water. Fuel charging necessitates a complete shut down and is done under water through the removable cover plate. The reactor and its upper tank are in turn contained in a large tank and the pressure vessel is surrounded by a series of coaxial shells providing a 47-inch thick iron-and-water shield. The containing tank is of steel surrounded by 2ft of concrete. This tank also provides



Shielding is by multiple layers of steel and water. Control rods operate from below core: ones shown here are partly 'out.' Coolant inlet is on the left—outlet on right. For fuel charging, pressure vessel cover plate is removed and rods manipulated through upper shielding tank



The core of the first Alco packaged reactor (APPR-1) contains 44 fuel elements, and five control rods

support for the pressure vessel which is held on a plane just below the inlet and outlet nozzles.

The entire nuclear side of the plane—reactor, heat exchanger, pumps and fuelling apparatus—is contained in a cylindrical building with domed ends known as a vapour container. This is of sandwich construction with steel 'bread' and concrete 'meat,' and in intended to contain fission products in the event of an accident. Access to the reactor is gained through a cylindrical port in the side, the hollow door of which is filled with water while the plant is critical. When personnel have to enter the vapour container, the air is filtered and conditioned. The conventional parts of the APPR—the turbine hall, water treatment plant, control room, etc.—are housed in a simple two-storey building alongside the vapour container.

For the proposed 10MW plant, the following outline specification was issued:

REACTOR

Thermal power	46,000 kW
Electrical output gross	10,600 kW
Electrical output net	10,000 kW
Thermal efficiency	22%
Uranium enrichment	4-12%
Fuel charge (fabricated)	$1\frac{1}{4}$-$3\frac{1}{2}$ tons
Core life between refuellings	
100% load factor	18 months
80%	30 months
Control rods	7 to 9
Average fast flux	5×10^{14} n/cm²/sec
Average thermal flux	10^{14} n/cm²/sec
Temperature coefficient	-2×10^{-4} per °F in k

PRIMARY LOOP

Pressure	1,500 lb/in²g
Flow—varies with enrichment, typically	9,000 gal/min
Coolant temp, reactor inlet (typical)	485°F
Coolant temp, reactor outlet (typical)	518°F
Pressure vessel	$4\frac{1}{2}$ft dia. by 16ft high

All surfaces in contact with primary coolant and fuel element sheaths are of stainless steel. Fixed rate of blowdown and equivalent make-up through demineralizers maintain coolant purity.

SECONDARY LOOP

This depends largely on turbine installed but a typical specification would be:

Turbine stop valve conditions	375 lb/in²g, 439°F
Flow to condenser	174 klb/h
Back pressure	2.5 in Hg
Feed temperature	280°F

CONTROL SYSTEM

The reactor shuts down automatically on the following signals: Pressure (high or low) in pressurizer, level (high or low) in pressurizer, coolant outlet temperature (high), steam pressure (high), steam temperature (high), primary coolant flow (low), coincidence of two parallel circular plate ion chambers, reactor period less than 3secs, or manual scram. The rods commence to drop in about 60 milliseconds with an initial acceleration of 24ft/sec².

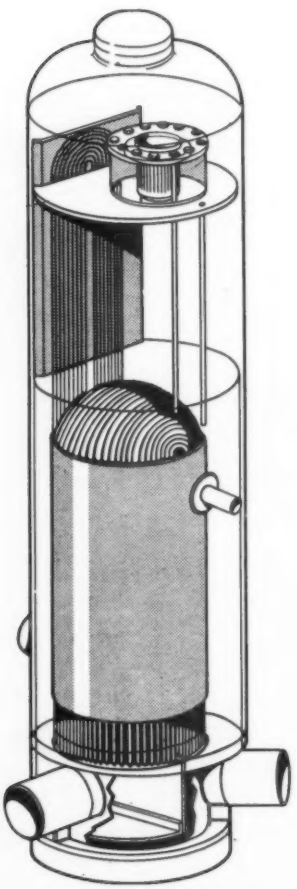
The primary coolant blow-down and make-up are recorded and the conductivity is recorded both before and after the demineralizers.

SHIELDING

Primary shielding is of the iron-water type as in APPR-1. Secondary shielding of 3 to 4ft of concrete surrounds the primary loop equipment. The vapour container, which also provides biological shielding is about 70ft dia. and 70ft high. Fresh fuel is kept in a vault and spent elements in a cooling pit until they are ready for transport.

COSTS

Humphreys and Glasgow Ltd stated that the total cost of a 10MW plant would be about £2m, including the cost of leasing enriched fuel from the AEC. Running costs were stated to be between $1\frac{1}{2}$d and 2d a unit. Initially about $\frac{1}{3}$ of the plant would be built in the UK but eventually it is proposed to manufacture it all, with the exception of the fuel elements which will continue to come from the United States AEC. Much of the manufacturing will be done by Daniel Adamson and Co Ltd, Dukinfield.



In the heat exchanger a separate bank of hairpin tubes gives the steam a mild superheat. The outlet is at back in this view

Rapid identification of metals

The basic design of the new Solartron Metal Sorter and Resistivity Test Set, Type MM 611, originated from The British Aluminium Company Ltd, one of the largest of the British manufacturers of light alloys. The instrument is operated by dry batteries and may be used in open-air stockyards and scrap metal yards or anywhere else where there is no electricity supply.

The set consists of an investigating head on a lead, which is plugged into a small instrument case. The head is placed on the metal surface, which need not necessarily be flat, because the measurement of the resistivity of a metal is not critically dependent on the spacing of the head from the surface of the metal under investigation.

Identification is based upon the specific resistivity of the particular metal. Because this is a physical constant of which every metal and alloy has its own specific value, its measurement gives a figure which identifies the metal being tested.

When the test head is brought near to the metal, its inductance changes. The oscillator in the instrument case ceases to oscillate. The calibrated dial is rotated until the oscillator comes into action again. This point is indicated by the left-hand meter, and the reading of the calibrated dial at this point is the specific resistivity of the metal in micro-ohms per centimetre cube.

Provided the metal or alloy has a specific resistivity between 1·0 to 28·0 micro-ohms per centimetre cube, it may be measured, or, inversely, the metal or metals distinguished or sorted.

Four metal standards are provided below the calibrated dial, by means of which the instrument's calibration may be checked and the necessary correction is made by the calibration control on the panel.

The wide scope for this instrument is indicated by the following examples of materials it can test: Pure copper, pure aluminium and alloys, molybdenum, radium, tungsten, cadmium, rhodium, zinc, platinum, tin, tantalum, magnesium, lead and tellurium and, of course, many of their various alloys. The following are some applications of the instrument:

1. Sorting of metals and alloys
2. Quick and accurate measurement of electrical resistivity
3. Detection of the clad side of rod, sheet, tube and bar, whether as a raw material or partly or fully fabricated
4. Inspection of the uniformity of cladding, coatings, etc
5. Detection of local variations in hardness
6. Detection of surface flaws
7. Detection of embedded foreign matter
8. The testing, from one side only, for variations of thickness, within certain limits

There is no upper limit to the size or complexity of shape of the metal structure to be examined for any of the above data. The minimum requirements are that the surface must be sensibly smooth, but need not be flat, and the test portion should have a minimum diameter of 0·75 in. and have a minimum thickness of approximately 0·02 in.

The Portable Metal Sorter and Resistivity Meter enables surveys, or examinations to be carried out in either confined spaces inaccessible to normal size equipment, or on large structures, which are too big for the test house. Shipbuilding, the aircraft, atomic energy and the heavy electrical industries are examples.

The Solartron Electronic Group Ltd.
Thames Ditton, Surrey

5-decade scaler is portable, rugged

The first transistorized portable scaling unit, Type 1287A, was recently announced by Dynatron. This is a completely portable five-decade scaler, designed for arduous use in the field, or any situation where essential requirements are compactness and independence of mains supply. The addition of a suitable geiger-müller tube completes this equipment which is highly suitable for the detection and measurement of radioactivity in geological surveys, mining and many other applications.

The scaler provides a polarizing voltage of the range of 350V-435V, suitable for the halogen-quenched type of geiger-müller tube. Pulses from the tube are fed to a five decade scaling circuit of adequate sensitivity and resolving time for g-m counting. This circuit comprises five cold cathode dekatron tubes driven by germanium junction transistors, enabling a total of 99,999 counts to be registered. A robust built-in stopwatch provides automatic timing, and two methods of counting can be performed. In the first, the stopwatch is started in synchronism with the start of the scaling unit, and is then stopped electronically when the end of a pre-selected total count of 10^2, 10^3, 10^4 or 10^5 is reached. In the second method, the stopwatch is started in synchronism as before but is used to monitor the desired counting period and the watch must be manually stopped to stop the scaling unit counting.

Scaler incorporates stopwatch. Battery box is separate

Further features of this transistor operated scaler are the built-in test pulse generator which provides fast or slow 'self-test' facilities at the operation of a spring-loaded switch and, also controlled from the same switch, a small meter which gives indication of battery voltage.

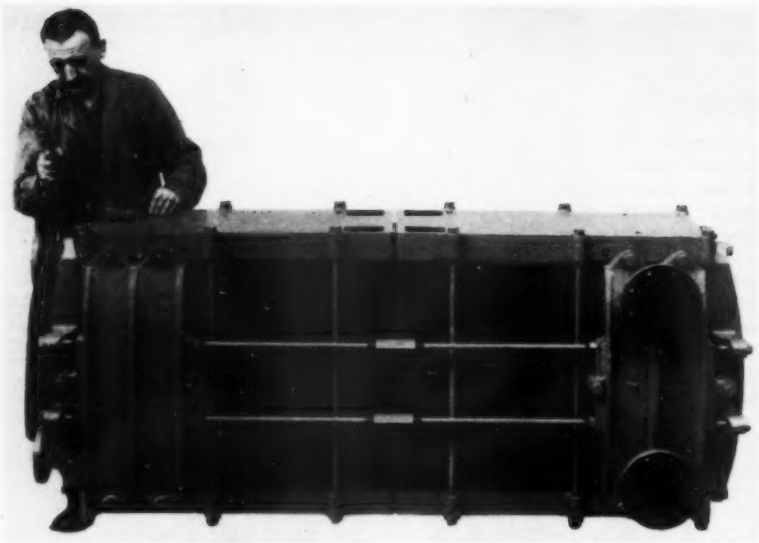
Dynatron Radio Ltd, The Firs, Castle Hill, Maidenhead, Berks

d.c. pneumatic timer

The range of applications for Square D pneumatic timers has been increased by the introduction of a d.c. version. The new timer, designated Class 9050 Type Q, incorporates all the features found in the a.c. version. Simple adjustments enable the time setting to be varied and also to convert the device from time delay after energization to time delay before energization or vice versa. One or two auxiliary switches operating directly from the timer magnet can be fitted and normally consist of a double circuit contact mechanism.

The basic pneumatic unit is so designed to be impervious to fluctuations in atmospheric pressure and ambient temperature. The operating principle is based on the interval required to transfer a small volume of filtered air from an upper to a lower chamber through a regulated orifice. A knurled knob gives adjustment from 0·2 seconds to 3 minutes in an infinite number of steps. Class 9050 Type Q Timers are available with operating coils for voltages up to 250 d.c.

Square D Ltd,
100 Aldersgate St, London, EC1



This unit has an effective surface area of 200 sq. ft

Bigger graphite heat exchangers

The continuing successful use of *Delanium* graphite cubic heat exchangers in all industries confronted with problems of corrosion has created a demand from chemical engineers for graphite block exchangers with larger heat transfer areas and larger tube diameters. To meet this need Powell Duffryn Carbon Products has developed a series of large rectangular graphite block heat exchangers which are now available. The new series consists of three standard models with effective surface areas of 100, 150 and 200 sq ft and tube or hole diameters of $\frac{3}{4}$ in. The design of the new models is basically that of the patented cubic heat exchanger except that the dimensions of the graphite block have been extended and the flow patterns modified to suit the altered shape of the block.

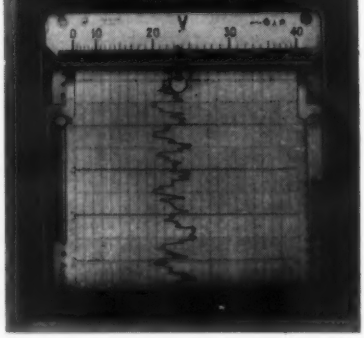
Multiple pass arrangements of up to 16 passes on either side are available to suit the flow rates of both liquors and to ensure minimum pressure drop. There are no floating or flexible parts and the new series embodies all the advantages of corrosion resistance on both sides, high thermal conductivity, compactness, robustness and ease of maintenance for which *Delanium* graphite cubic heat exchangers are well recognized.

Powell Duffryn Carbon Products Ltd,
Springfield Road, Hayes, Middlesex

Swiss miniature chart recorders for UK

A miniature switchboard chart recorder known as the *Minireg*, made by Trüb, Täuber of Zürich is now available in the UK through British agents. These instruments are for voltage, current and watts recording on single phase and for watts and varmeter records on three phase 3-wire systems. The recorders have a 4¼in. chart, giving 4½ hour visible record with a frontal area of only 5¼in. by 5¼in. The chart drive is by synchronous motor or by hand or electrically wound clockwork. Faster chart speeds are available if required. Record trace is either by reservoir pen or inkless system on metalized paper.

Stonebridge Electrical Co Ltd,
6 Queen Anne's Gate, London SW1



The Minireg is only 5¼ in. square

The GR Red Box in production

A production model of this lightweight ratemeter from General Radiological Ltd—the prototype was described in NP July, 1956—is now available. This unit is compact—it measures 7 in. by 5 in. by 1¼ in. and weighs only 3 lb all told—and is fully sealed and tropicalized. It is suitable for rapid search work or for accurate measurement, and while particularly suitable for geological survey work, it can also be used in general laboratory monitoring. A distinctive feature is the bright scarlet finish giving easy location.

The ratemeter, which is built into a watertight metal case, is fitted with a desiccator and can operate at extremes

Ratemeter weighs only 3 lb

of temperature, pressure and humidity. The batteries are of internationally available type and easily replaceable. The battery container is completely sealed off from the body of the instrument. For easy field servicing, the whole of the lower part of the case is removable, giving access to the assembly. The high voltage current for the g-m tube is supplied from a transistor circuit and is very carefully stabilized so that voltage fluctuation due to battery discharge causes no loss of accuracy. The h.v. circuit accommodates a range of geiger counters between 350 and 450V.

Two ranges provide full scale deflections for dose rates of 0·5 and 5 mr/h; the latter dose rate is found in areas where the bed rock contains 0·05 per cent U_3O_8. The deaf-aid type earphone attachment, which can be plugged into the main unit, gives audible indication of the degree of radioactivity. This addition to the circuit causes a negligible increase in load and accuracy is not appreciably affected.

All components are of approved pattern and the instrument has been subjected to the usual vibration and drop tests. Battery life is in excess of 600 hours.

General Radiological Ltd,
15/18 Clipstone Street, London, W1

New 20th Century tube counts betas down to 60 keV

A new addition to the already large range of counters produced by 20th Century is the type EW2A mica end-window counter with organic quenching and improved stability.

The EW2A has two particular applications, the first being the assay of samples of low beta-emitters; in this respect the employment of mica end-windows of between 1 and 2·5 mg/cm² in thickness permits the efficient use of the counters with beta-radiation as low as 60 keV.

The second application is in the measurement of low activity samples of beta-emitters; to enable this, materials and design have been chosen to reduce the background and improve the counting stability. This makes possible the measurement of very low sample activities as well as reducing the necessary counting time for normal samples. The type EW2A counter will operate satisfactorily in lead castles manufactured by Ekco, ERD and Labgear and is interchangeable with the CV.2139.

A rubber cap protects mica end-window (left)

For the measurement of very low activity samples the counter may be mounted in the anti-coincidence shield (G.M. Tube assembly AERE Type 1224A) consisting of 12 20th Century G.24 Counter tubes. A rubber cap is supplied to protect the counter's fragile window; flexible, stranded-copper leads which ensure positive trouble-free contacts are also provided.

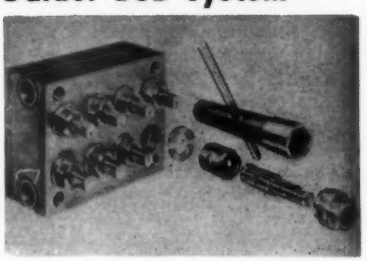
20th Century Electronics Ltd,
King Henry's Drive, New Addington
Croydon, Surrey

Klinger cocks chosen for Calder BSD system

A number of 3-way sleeve-packed cocks were specially made by Richard Klinger Ltd for the gas monitoring system in the Calder Hall reactors. The reactor cores are divided into eight areas, each of which is controlled by a 54-point gas sampling plant. From each area, 212 sampling pipelines are led through a Klinger 8-unit cock manifold which reduce the number of channels to 53. The sampling pipes are welded into the manifold cock bodies and these are mounted on the same framework as a 54-way rotary selector valve.

Each individual cock is sealed by a renewable sleeve of asbestos which is compressed around a perfectly parallel plug with a lapped finish. Stainless steel eyelets in the sleeve protect the packing from the action of the passing fluid. The position of the eyelets is fixed by means of a ridge on the outside of the packing sleeve which fits into a corresponding groove in the body.

The illustration shows an 8-unit AB. 18 cock manifold with one of the cocks dismantled. The split ring fits into the groove at the bottom of the plug and locates it firmly in an axial direction when the compressed asbestos packing sleeve is forced against it by the tightening nut. The body and the plugs are made from wrought stainless steel. The square ends of the plugs are unsymmetrical and a special operating key is provided to ensure that the ports in the cocks are positioned correctly. When the operating key is reversed it provides a box spanner which is used to tighten the nut compressing the packing sleeve. A special extracting tool is supplied for removing the plug from the body should the cock require repacking. All pipe connexions are welded and an annular recess is machined around each connexion in the body to relieve welding stresses. In order to prevent the risk of any leakage whatsoever, each group of four cocks is covered by a sealed bonnet which is only removed when the cocks are to be operated.



Special tool is used for dismantling

Proof of the satisfactory working of these cocks was disclosed recently when one of the reactors at Calder Hall was closed down in an endeavour to trace a leak of carbon dioxide. In the course of the tests all the Klinger cocks on the reactor were proved to be absolutely free of blame and operating in an entirely satisfactory manner.

Richard Klinger Ltd,
Klingerit Works, Sidcup, Kent

Plumbing with a paint brush

Durapipe polythene piping at Crittall Mfg Co Ltd

Developed by Richard E. DuPont Ltd, for use with their *Durapipe* range of polythene pipes and fittings a method of jointing has been introduced, using a solvent or an adhesive cement. This jointing process is extremely simple and no special training or equipment is required since the solvent welding compound is applied with a paint brush to the end of the pipe and the inside of the fitting, the pipe is inserted, turned once or twice (or driven home with the larger sizes). The connexion is then complete. Jointing by such simple methods as this can cut the time of installation of industrial pipework systems from days to hours in many cases.

Another important new material, Ziegler polythene known as *Durapipe Z*, is also being used by the company to make pipes and fittings. There is no common solvent for polythene and the waxy surface does not encourage the use of adhesives. Dr Röttner of the German Hoechst Chemical Co who manufacture Ziegler polythene, discovered that if the oxidized surface could be removed, polythene would adhere to polythene and this has resulted in the evolution of a simple and effective jointing technique. The surfaces to be jointed are heated to melting point, the oxidized layers removed and the surfaces then blended together. This is aided by the use of a blending iron, consisting of a round section of bronze or stainless steel turned at one end with a recess to fit over the pipe and with a pin at the other end for the fitting. The tool is heated to 600°C by blowlamp and the pipe ends heated in the tool for 10 seconds. The pipe is then gently pressed into the fitting and the joint is now complete. The surplus oxidized skin of the pipe and fitting is removed by this action so that the two surfaces blend perfectly together.

Richard E. DuPont Ltd
56 Kingsway, London WC2

High welding speeds with CO_2 shield

What is claimed to be the first new approach to welding for some years is the report from Quasi-Arc of their *Fusarc*/CO_2 process, a method of automatic arc welding evolved from the well-established *Fusarc* system. The electrode consists of the *Fusarc* patented type of continuous covered electrode with a newly developed type of covering, and this is used in conjunction with a carbon dioxide gas shield. This combination of flux and gas shielding allows considerably higher welding speeds than can be achieved with flux alone, and the deposited weld metal is of a high metallurgical standard.

The new process retains much of the well known tolerance of the *Fusarc* process towards ineffectively cleaned surfaces, mill scale, rust and dirt, and moreover allows horizontal-vertical fillets of a very high standard to be deposited by an automatic open-arc process for the first time.

Fusarc/CO_2 No. 1 electrode is the first electrode specially developed for use with a CO_2 gas shield. This is a general purpose electrode for horizontal-vertical fillet welding, single and multipass butt welding, and for fillet welding in the flat position. It is approved both by Lloyd's Register of Shipping and the Ministry of Transport.

The excellent mechanical properties of the weld metal are shown by the following typical results obtained on all-weld-metal specimens tested in accordance with BS.639:1952.

TENSILE TEST	Yield point	30·8 ton/in²
	Ultimate stress	35·5 ton/in²
	Elongation on 3·5 D	32%
	Reduction of area	70%
IMPACT TEST	Izod value	51 ft lb
BEND TEST	Specimens bent through 180° over a former equal to twice the diameter of the specimen without sign of failure	

Although the process deposits a low-hydrogen type weld metal, the electrode has a rutile covering and has the smooth easily controlled arc normally associated with this type of coating. At high welding currents there is a relative absence of spatter, and a high deposition efficiency is maintained. Deslagging is very easy even when the process is used at maximum welding currents.

The outstanding feature of the process is the ability to make horizontal-vertical fillet welds of high quality at high speed. Very high welding currents are used on comparatively small gauge electrodes. The process is, of course, also used for single pass and multipass butt welding, and, as a great degree of control can be exercised over the penetration, square edge butt welds are possible over a range of plate thicknesses from $\frac{1}{8}$ to $\frac{1}{4}$ in.

The flow rate of shielding gas is about 25 to 30 cubic feet per hour and need not be increased above these figures, even when fume extraction equipment is used. Maximum electrode feed is 100 in./min and maximum traverse speed is 100 in./min. *Fusarc*/CO_2 automatic arc welding heads are designed to operate at these speeds with welding currents up to 1400 amperes.

Quasi-Arc Ltd, Bilston, Staffs

Argonarc development for thin gauges

A new composite rectifier for the *Argonarc* welding process has been introduced. Known as the ACR.150, it has been developed to meet an increasing demand for small, comparatively lightweight equipment, giving a stable arc down to only a few amperes welding current. This set can be used for welding light gauge materials, with the exception of aluminium and magnesium base alloys, up to approximately $\frac{1}{4}$in. thick. It has a current range of approximately ten to 150 amperes, but lower currents can be obtained with an external resistance.

Apart from the stepless remote control current regulator, this set can be fitted with a spark starter and a crater-filling device (optional extra), comprising a series of relays, set to operate when the arc is broken at the end of the weld and causing the current to decay in steps. This device ensures that the weld crater at the finish of the weld cools sufficiently slowly to solidify with the least tendency to cracking. The current steps can be varied to give either a rapid or a slow decay between 2 and $3\frac{1}{2}$ seconds, according to the thickness of the material and the initial welding current employed.

A striking voltage of 70 is provided, to ensure rapid arc-striking throughout the current range, but more especially at very low welding currents.

Argon gas and water time delay economizers are also provided, which operate automatically when the arc is broken. Remote control of the spark starter and inbuilt contactor is made from a standard 25 volt two-position foot switch.

British Oxygen Gases Ltd
Sales Technical Service Department
North Circular Road, London NW2

A 200-gal industrial unit

Ceramic filters

Porous ceramic material has many advantages as a filtration medium. This is especially so when it is made to a carefully controlled specification to perform a given set of tasks. *Porsilex* and *Celloton* ceramic materials, as used in Aerox filters, are made with pore sizes ranging from 200 to 10 microns and the media have resistance to thermal shock and also to corrosive liquids.

Other attributes of the media are high pore density with uniform permeability throughout the media, providing minute openings for the passage of fluids and gases, together with the greatest possible tensile and compressive strength. These ceramics are, in general, easily machinable.

Aerox liquid filters, when supplied complete, vary from small glassware vessels of small capacity up to steel containers holding some 200 gallons. Modern industrial reaction processes are carried out at pressures ranging from a few inches of mercury to one atmosphere and a few at still higher pressures. The ceramic elements are variously disposed in the containers and may take the form of a single candle-type element or may be fitted in clusters of up to some 270 units per vessel.

The majority of industrial processes necessitate liquid filtration at some point in their production system and the advantages offered by porous ceramic filters account for their steady increase in popularity.

Aerox Ltd,
Lister Place,
Hillington, Glasgow, SW2

Reactor Physics-10

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As U-235 fissions, and isotopes of Pu build up, the reactivity changes. NUCLEAR POWER's basic course covers this

1. Changes in the effective multiplication constant

continued

We have said earlier that the density changes brought about by temperature changes cause only small changes in the critical size of a large thermal reactor. It can be readily shown that the value of k_e is reduced on increasing the temperature so this, in effect, adds a further negative temperature coefficient. For a typical natural uranium graphite reactor the coefficient due to density changes may be approximately $-0{\cdot}2\times10^{-5}$ per °C.

The other important change induced by temperature in a reactor is the change in pressure if a gaseous coolant is used. This is of particular significance if the moderator is porous, such as graphite which contains about 25–30% by volume of space which will also be occupied by the coolant gas. Again, for a typical graphite natural reactor the pressure coefficient, as it is called, is about -7×10^{-6} per millibar. Clearly the value of k_e decreases as the pressure increases because increased pressure simply means increased absorption in the coolant gas.

2. Changes in the fissionable material content

The way in which the burning up of the fissionable material affects the reactivity of a reactor is of great importance in the case of a power reactor which is required to run for a long time. It is essential that over the lifetime of the reactor the change in the multiplication constant is not too large and negative.

In a reactor using uranium as the fuel the changes which have to be taken into account are the destruction of the fissionable U–235 and the production of plutonium isotopes by neutron absorption initially in the U–238. The plutonium is produced by the following chain :

$$U^{238}+n \rightarrow U^{239} \rightarrow Np^{239} \rightarrow Pu^{239}$$

$$Pu^{239}+n \rightarrow \text{fission or } Pu^{240}$$

$$Pu^{240}+n \rightarrow Pu^{241}$$

$$Pu^{241}+n \rightarrow \text{fission or } Pu^{242}$$

So, although fissionable U–235 is burnt up, other fissionable material, namely Pu–239 and Pu–241 is produced. Pu–240 is not fissionable by thermal neutrons.

The cross-sections, half-lives and ν and γ_i values are given in Table 10.1

Isotope	σ_c	σ_f	T	ν	γ_i
U^{235}	107	580	$7{\cdot}1\times10^{8}$y (α)	2·46	2·08
U^{236}	9		$2{\cdot}40\times10^{7}$y (α)		
U^{238}	2·75		$4{\cdot}50\times10^{9}$y (α)		
U^{239}	22		23·5 m (β)		
Np^{239}	80		2·33 d (β)		
Pu^{239}	315	750	$2{\cdot}44\times10^{4}$y (α)	2·88	2·03
Pu^{240}	510		$6{\cdot}6\times10^{3}$y (α)		
Pu^{241}	380	1100	12·9y (β)	2·98	2·21

Table 10.1

Characteristics of nuclei occurring in uranium reactor. The cross-sections are in barns

ON DISCUTE brièvement l'effet des changements de densité dans une pile ainsi que l'effet des changements de pression lorsque le réfroidissement est effectué à l'aide d'un gaz. On examine les changements importants de réactivité, qui ont lieu par suite de la fission de U-235 et de la production de Pu-239, et l'on décrit les changements causés par la production ultérieure de Pu-240 et Pu-241. Quand on combine ces changements avec l'empoisonnement par le produit stable de la fission, il devient possible de déterminer la variation du facteur de multiplication de la pile en fonction de l'irradiation neutronique du combustible.

DIE EINWIRKUNG der Dichteänderungen in einem Reaktor, sowie der Druckänderungen des Kühlgases werden kürzlich erörtert. Man untersucht die wichtigen Reaktivitätsänderungen, die infolge der Spaltung von U-235 und Herstellung von Pu-239 zustande kommen, und man beschreibt die durch die weitere Produktion von Pu-240 und Pu-241 verursachten Änderungen. Vereinigt mit der durch das stabile Spaltungsprodukt verursachten Vergiftung, ermöglichen diese Änderungen, die Schwankung des Reaktor-Vermehrungsfaktors als Funktion der Neutronenbestrahlung des Brennstoffs aufzufinden.

LOS EFECTOS de los cambios de densidad en un reactor son discutidos brevemente, así como los correspondientes a los cambios de presión cuando se usa un gas como elemento enfriador. Se investigan los importantes cambios de reactividad que ocurren debido a la fisión del U-235 y a la producción de Pu-239, y se demuestran los cambios originados por la subsiguiente producción de Pu-240 y Pu-241. Estos cambios, cuando van combinados con un envenenamiento estable de productos de fisión, permiten encontrar la variación del factor de multiplicación del reactor como una función de la irradiación de neutrones del combustible.

ОБСУЖДАЕТСЯ вкратце влияние изменений плотности в реакторе, а также влияние изменений давления в случае газового охладителя. Исследуются значительные изменения реактивности, происходящие вследствие деления U-235 *и образования* Pu-239 *: описываются изменения, вызванные последующим образованием* Pu-240 *и* Pu-241. *На основании этих изменений, а также отравления постоянными продуктами деления становится возможным выразить изменение коэффициента воспроизводства в виде функции облучения топлива нейтронами.*

Now let us look at the chains in more detail. The destruction of U–235 is either by fission or neutron capture to produce U–236, but we are here concerned primarily with the removal of U–235 whatever the method, so the number of U–235 atoms $N(5)$ at time t is given by

$$\frac{dN(5)}{dt} = -N(5)\phi\sigma(5) \qquad (10.1)$$

where $\sigma(5)$ is the absorption cross-section and ϕ the thermal neutron flux. So

$$N(5) = N_o(5)e^{-\phi\sigma(5)t} \qquad (10.2)$$

where $N_o(5)$ is the number of U–235 atoms initially present. For convenience we introduce a quantity x defined by

$$x = (N(5)-N(5))/N_0(5) = 1-e^{-\phi\sigma(5)t} \qquad (10.3)$$

so that x is the fraction of U–235 burnt up, or the depletion as we shall call it.

It is usual to quote depletion figures in terms of the number of megawatt days per tonne irradiation of the fuel. This requires a knowledge of the flux ϕ and the time t and then $\phi\sigma(5)t$ and hence x is known.

The average flux in a reactor can be found in terms of the characteristics of the fuel, the power of the reactor and the amount of fuel in the reactor. For thermal fission of U–235, $3{\cdot}1 \times 10^{10}$ fissions per second produce one watt (*see Article 1*), so if the reactor is producing Q MW the total number of fissions per second is

$$3{\cdot}1 \times 10^{10} \times Q \times 10^{6} \qquad (10.4)$$

But if ϕ is the average flux in the reactor the number of fissions per second is also the product of the flux, the number of fissionable atoms and the fission cross section per fissionable atom. For natural uranium this is then

$$\phi \times \frac{0{\cdot}6023}{239 \times 139} \times U \times 10^{6} \times 580 \qquad (10.5)$$

where U is the tonnes of natural uranium. Equating (10.4) and (10.5) gives

$$\phi = 2{\cdot}94 \times 10^{12} \frac{Q}{U} = 2{\cdot}94 \times 10^{12} \times \text{MW per tonne} \qquad (10.6)$$

It should be noted that the figure usually quoted as the flux of a reactor is the maximum flux and not this average and so will be larger than ϕ from (10.6).

Returning now to (10.3), a given depletion means a value of $\phi\sigma(5)t$ and then using (10.6) this value of $\phi\sigma(5)t$ can be converted into a value of MW days per tonne, namely,

$$\text{MW days per tonne} = 5730\ \phi\sigma(5)t \qquad (10.7)$$

Table 10.2 shows the depletion of U–235 in natural uranium as a function of the MW days per tonne :

Depletion in %	5	10	15	20	25	30	35	40	45	50
MW days per tonne	294	604	931	1280	1650	2040	2470	2930	3430	3970

Table 10.2
U-235 depletions as a function of irradiation

The production of U–236 by neutron capture in U–235 is also important, and is most simply considered as being a poison. Although it has a small cross-section (9 barns) it has effectively a very large fission yield because every fission of U–235 produces $\sigma_c(5)/\sigma_f(5)$ U–236 atoms and so its fission yield is effectively $107/580 = 18{\cdot}5\%$. The equation for the production of U–236 is

$$\frac{dN(6)}{dt} = N(5)\phi\sigma_c(5) - N(6)\phi\sigma(6) \qquad (10.8)$$

$$\text{so} \qquad N(6) = \frac{N_0(5)\sigma_c(5)}{\sigma(5)-\sigma(6)}\left[e^{-\phi\sigma(6)t} - e^{-\phi\sigma(5)t}\right] \qquad (10.9)$$

But $\sigma(6)$ is small compared with $\sigma(5)$ so (10.9) can be written approximately as

$$\frac{N(6)}{N_0(5)} \simeq \frac{\sigma_c(5)}{\sigma(5)}\left(1 - e^{-\phi\sigma(5)t}\right) = 0{\cdot}16x \qquad (10.10)$$

Turning now to the depletion of U–238 the situation here is much more complex. However, for the purpose of this discussion we can simplify things by first of all supposing that U–238 leads directly to Pu–239. This is justified because the half-lives of U–239 and Np–239 are short and the Np–239 cross-section is not excessively large.

Now U–238 is depleted in three ways—by thermal and by resonance capture and also by fast fission and capture. The thermal capture term in the equation for $dN(8)/dt$ is simply $N(8)\phi\sigma(8)$. However, the resonance capture term is rather more complicated. It can be arrived at by the following argument.

Every fission neutron produces ε fast neutrons of which a fraction $1\text{-}p$ are absorbed by resonance capture. So we must multiply $\varepsilon(1\text{-}p)$ by the rate of production of fission neutrons. This however, is not simply the rate of production from U–235 fission but from Pu–239 fission and Pu–241 fission also. To simplify again we shall neglect fission in Pu–241 as this anyhow only becomes significant for long irradiations. Also we shall neglect the destruction of U–238 by fast fission and fast capture. This is a small effect and is again proportional to the fission rate and so can be simply included if required. So finally, we get

$$-\frac{dN(8)}{dt} = N(8)\phi\sigma(8) + \phi[N(5)\sigma(5)\eta_f(5) + N(9)\sigma(9)\eta(9)]\varepsilon(1\text{-}p) \qquad (10.11)$$

using ' 9 ' to denote Pu–239.
As the destruction of U–238 by fast neutrons has been neglected, all the U–238 destroyed becomes Pu–239 and so

$$\frac{dN(9)}{dt} = -\frac{dN(8)}{dt} - N(9)\phi\sigma(9) \qquad (10.12)$$

and for Pu–240, as it is produced by capture in Pu–239

$$\frac{dN(0)}{dt} = N(9)\phi\sigma_c(9) - N(0)\phi\sigma(0) \qquad (10.13)$$

using ' 0 ' to denote Pu–240.

Similar equations can be written down for Pu-241 and Pu-242 if necessary.

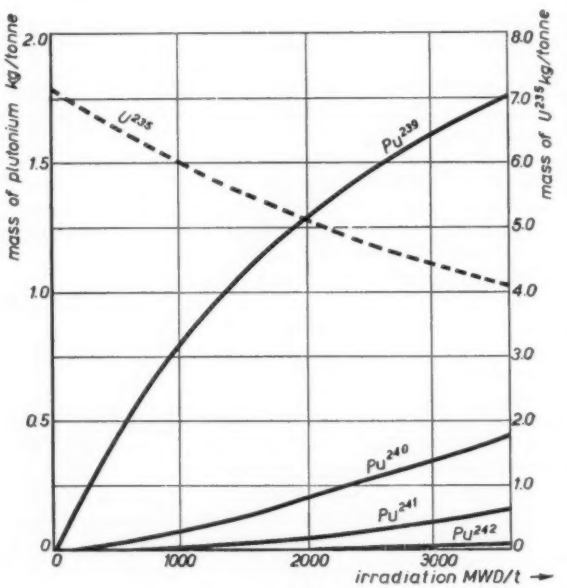


Fig. 10.1 Isotopic composition of irradiated natural uranium in the Calder type reactor

The equations (10.11), (10.12) and (10.13) can be easily solved for N(8) N(9) and N(0) respectively. Curves of these quantities against irradiation are shown in Fig. 10.1 (Cockcroft: NP 1 V, p 202) for a Calder Hall type reactor. For small values of the depletion these solutions give as a function of x

$$\frac{N(9)}{N_0(5)} = z$$

$$z \simeq Cx - \frac{x^2}{2}\left[C\frac{\sigma(9)}{\sigma(5)}\left\{1-\varepsilon(1-p)\gamma_i(9)\right\} - \frac{N_0(8)\sigma(8)}{N_0(5)\sigma(5)}\right] \quad (10.14)$$

and

$$\frac{N(0)}{N_0(5)} = q \simeq C\frac{x^2}{2}\frac{\sigma_c(9)}{\sigma(5)} \quad (10.15)$$

where C is the conversion factor defined in (7.20) by

$$C = \frac{N_0(8)\,\sigma(8)}{N_0(5)\,\sigma(5)} + \varepsilon\,\gamma_i(5)(1-p) \quad (10.16)$$

Because the U-238 cross-section is small compared with the U-235 cross-section, the depletion of U-238 is small compared to that of U-235 and for small x can be neglected. For not too large depletions it can be assessed approximately by modifying (10.11) and assigning an effective U-238 cross-section $\sigma'(8)$ by putting

$$\sigma'(8) = \sigma(8) + \gamma_i(5)\varepsilon(1-p)\sigma(5)\frac{N_0(5)}{N_0(8)} \quad (10.17)$$

$$= C\frac{N_0(5)\,\sigma(5)}{N_0(8)} = \frac{687}{138}C$$

$$= 4{\cdot}98\ C \text{ barns for natural uranium}$$

Then (10.11) gives

$$N(8) = N_0(8)e^{-\phi\sigma'(8)t} \quad (10.18)$$

It can be seen from (10.14) that for small values of depletion the number of Pu-239 atoms present per U-235 atom destroyed is approximately the conversion factor. However, as the irradiation proceeds more and more Pu-239 and U-235 will be burnt up and so this ratio will start to decrease, and so a more general conversion factor can be defined as z/x which is the number of Pu-239 atoms present per U-235 atoms destroyed.

Equation (10.15) simply shows that, because Pu-240 cannot be made until Pu-239 has been made, the amount of Pu-240 present for small irradiations is small compared to amount of Pu-239 present.

3. Effect of these changes on the multiplication constant

We now wish to find the effect of these changes on the k of a reactor. This discussion can be simplified because the changes in ε and p can be neglected except for large irradiations. This is because ε and p depend on the number of U-238 atoms present and we have said that this only changes very slowly. For example, after a 25% depletion of the U-235, that is an irradiation of about 1650 MW days per tonne the U-238 depletion is only about 0·17% in a typical natural uranium reactor.

Thus we need only calculate the changes in γ_i and f. Consider first γ_i. If there is more than one fissionable material present the definition of γ_i can be extended, from (5.30), to

$$\gamma_i = \frac{N(5)\sigma(5)\gamma_i(5) + N(9)\sigma(9)\gamma_i(9)}{N(5)\sigma(5) + N(8)\sigma(8) + N(9)\sigma(9) + N(0)\sigma(0)} \quad (10.19)$$

in the case in which Pu-239 and Pu-240 are present. So, knowing the values of $N(5)$, $N(9)$ and $N(0)$ for any irradiation, γ_i can be calculated as a function of the irradiation.
Again for the thermal utilization f. This is defined by

$$\frac{1}{f} - 1 = \frac{\text{absorption in materials other than fuel}}{\text{absorption in fuel}} \quad (10.20)$$

so for a particular reactor

$$\frac{1}{f} - 1 = \frac{\text{constant}}{\text{absorption in fuel}}$$

$$= \frac{\text{constant}}{N(5)\sigma(5) + N(8)\sigma(8) + N(9)\sigma(9) + N(0)\sigma(0)} \quad (10.21)$$

which can again be found as a function of the irradiation. For small depletions the change in k, Δk, is given by

$$\frac{\Delta k}{k_0} \cong x\left\{C\frac{\sigma(9)}{\sigma(5)}\left(\frac{\gamma_i(9)}{\gamma_i(5)} - \frac{f_0\gamma_0}{\gamma_i(5)}\right) - \left(1 - \frac{f_0\gamma_0}{\gamma_i(5)}\right)\right\} \quad (10.22)$$

where k_0, f_0, γ_0 are the initial values.
Now it is of great importance in a reactor which has to run a long time that the change in k due to these effects is positive for a considerable time, otherwise the k would steadily decrease. From (10.22) it can be seen that where k initially increases or decreases in the reactor depends almost entirely on the value of the conversion factor C. To get an approximate idea suppose $\gamma_i(9) = \gamma_i(5)$, which is approximately true. Then Δk is positive initially if

$$C\sigma(9) > \sigma(5)$$

or

$$C > 687/1065 = 0{\cdot}65 \quad (10.23)$$

so that the k will increase initially if C is approximately greater than 0·65 and the rate of increase of k will be greater the greater C is than this value. Then, as the irradiation proceeds k will continue to increase. But eventually Pu-240 will be built up an appreciable extent and because this is not fissionable it will retard the increase of k simply by absorbing neutrons. Ultimately as more is produced the curve will turn over and eventually k will return to its initial value and then drop below this steadily. Again, ultimately there will be some positive effect from the build up of fissionable Pu-241.

Superimposed on this will be the effect of the stable poisons which will always worsen the situation. Sm-149 builds up

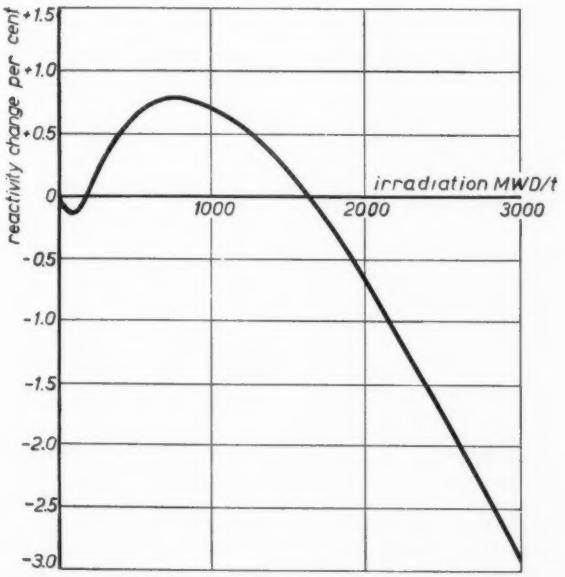


Fig. 10.2 Reactivity variation with irradiation for a uniformly irradiated Calder type reactor

quite rapidly and eventually there is a steady increase in the poisoning as other long term poison gradually builds up.

A typical curve of the variation in k as a function of irradiation for a Calder Hall type reactor is given in Fig. 10.2 (Cockcroft: NP 1 V p 200). Here k returns to its initial value after an irradiation of about 1600 MW days per tonne.

4. Moderator 'Clean up'

One further type of reactivity change which may take place is due to the decrease in cross-section of the moderator. A moderator such as graphite inevitably contains impurities, and these in the main happen to be very small quantities of high cross-section atoms and may contribute something like 1 millibarn to a graphite cross-section of 4·8 millibarns. So as the graphite is irradiated these impurities, because of their high cross-sections, will preferentially absorb neutrons and be converted into low cross-section nuclei. Then as the irradiation proceeds the graphite cross-section, and hence absorption, decreases with a corresponding increase in the multiplication constant.

Note

In Fig 9.1 of the previous instalment, the scale shown on the right-hand side of the graph applies only to a flux of 10^{14} after shut down.

BOOKS

Radiation Dosimetry Ed. Gerald J. Hine and Gordon L. Brownell. 6½in. by 9¼ in. 932pp + 306 figs. New York 1956: Academic Press Inc. London: Academic Books. Price 157s.

In recent years the subject of radiation dosimetry has multiplied rapidly with the vast production of artificial radioactive materials by nuclear reactors and the increasing use of high-voltage accelerators of all kinds. The continuing growth of the subject has created a need for a book dealing with the many new branches of radiation dosimetry, putting them into perspective with regard to the older parts of the subject. The new book edited by Gerald J. Hine and Gordon L. Brownell appears to meet this need.

Naturally a book dealing with radiation dosimetry for those working with applications of radiation to medical, industrial and research problems represents a fair undertaking. The basic techniques of the subject are the same in all cases, but the detailed problems encountered, including the problems of health physics and instrumentation require a slightly different approach according to the nature of the source of the radiation and its characteristics. It is to be expected therefore that many specialists would need to be consulted to produce a work of this kind, and, in fact, the present volume is the work of 22 contributors, including a number of British authorities such as Professor F. W. Spiers and Dr J. W. Boag.

The book is divided into three parts. The first part presents the fundamental principles of dosimetry. The first chapter in this section is by Professor Spiers and deals with the physical properties of radiation and their interaction with matter, whilst the later chapters deal with the basic biological and medical effects. The preliminary chapters are very well done and form a most valuable introduction to the subject.

The second part of the book describes the various instruments used for detecting radiation and measuring its characteristics. It includes information on scintillation detectors, photographic film, chemical and colorimetric indicators and calorimetric methods from the point of view of their applications in the field of dosimetry. There are eight separate chapters in this part of the book, each written by a specialist and some of them are really excellent. The standard varies, however, and in places the presentation is unbalanced, the treatment of the detector components themselves is first-class, but details of the associated measuring circuits are often not included. It would have been better if there could have been a greater integration of these chapters by the Editors. Chapter 10 on *Survey Instruments and Pocket Dosimeters* for example, contains useful information to the reader, but much of this is presented in a more complete form in the earlier chapters and data which might have been expected in this chapter regarding the detailed design of the instruments described are not included. Whilst making this criticism, however, the reviewer should make it clear that this second part of the book is full of most useful information and a number of the chapters are most admirable surveys of the subject. The reviewer was, for example, most impressed with the valuable chapters on *Ionization Chambers* (Chapter 4) and the *Standardization of X-Ray Beams and Radioactive Isotopes* (Chapter 11).

The third part of the book presents the problems of dosimetry of various radiation fields, and includes chapters on X-rays and Teleisotope Gamma-Sources, high-energy electron beams, beams of heavy charged particles, neutrons and mixed radiations, discrete radio isotope sources, and internally administered radio isotopes. The treatment here is good and detailed, and in some cases is appearing for the first time.

The book ends with a chapter on *Isotope Shipment and Disposal* and an Appendix containing data useful for dose calculations.

The book is well printed and illustrated, and each chapter ends with detailed references to the original literature. As a work of reference, the book can be strongly recommended to all those concerned with the measurement of radiation.

Denis Taylor

Metallurgy of the Rarer Metals: Molybdenum L. Northcott. 6in by 9 in, 222 + xii pp. London 1956: Butterworths Scientific Publications. Price 40s.

With the ever-increasing demand for high-melting-point alloys of good mechanical properties, greater attention has been directed to the study of molybdenum and molybdenum-rich alloys. Since the development of arc-casting techniques for molybdenum, the metal has become available in useful engineering quantities and in post-war years research has been directed mainly towards studying its mechanical properties.

Dr Northcott's book gives a thorough discussion of the occurrence of molybdenum in nature and the methods used to extract it from its ores. The fabrication of molybdenum by powder metallurgy and arc-casting techniques is discussed in detail and a review is given of the work on its mechanical properties, with special reference to the ductile-brittle transition. Separate chapters are devoted to the problems caused by its low oxidation resistance and to the severe difficulties experienced in joining the metal.

The chapter on molybdenum alloys is extensive and contains a useful collection of phase diagrams. A separate chapter is devoted to the mechanical properties of molybdenum alloys; in particular, their transition temperature and creep-rupture properties are discussed.

One of the most valuable features of the book is the large collection of references. However, from the physicist's point

of view the collection is not complete. For example, the author leaves his reader with the impression that the thermal and electrical conductivities of the metal have been measured down to 90°K and 14°K respectively, and not below. In fact, to mention only two recent sets of measurements, Mendelssohn and Rosenberg (1952) have measured the thermal conductivity of molybdenum at liquid helium temperatures, and Thomas and Mendoza (1952) measured its electrical conductivity down to 0·05°K, and observed a super-conducting phase in annealed specimens.

However, these are minor omissions in what is in every other way a most useful book. For the reviewer, who has recently become interested in the metallurgy of molybdenum, it has provided a comprehensive introduction to this field. It has also greatly lightened the task of becoming acquainted with the published literature of a specialized part of the subject.

A. A. Johnson

Nuclear Reactor Data—2nd Edition Waltham, Massachusetts, USA 1956: Raytheon Manufacturing Co

The latest edition of this valuable work catalogues leading technical data of 140 reactors—operating, building or projected. The reactors are arranged in groups according to type and the general layout is most pleasing and easy to follow.

In an accompanying statement, the publishers note that the catalogue lists four power plants to be built in Britain by 1970. This is of course quite incomplete even by the 1955 White Paper plan which visualized 12 by 1965.

An interesting speculation surrounds the first Soviet pile. This was described and illustrated in a recent book but nowhere in the article was there any mention of the date when it started up. Nor is there here. While this is of little scientific interest now, it would be interesting from an historical point of view to find out.

Reactor Shielding Design Manual ed. Theodore Rockwell III 8½in by 10½in. 477pp. New York 1956: McGraw Hill. London 1956: Macmillan. Price 42s.

This shielding manual is concerned with describing the methods and the experimental basis of the shielding calculations used in the United States Naval Reactor Programme, and in the Shippingport PWR design. The principles upon which the calculations are based are common to all types of reactor. It may therefore be expected that the results of investigation of the particular types of reactor and shield considered in this book will be invaluable in designing shields for other types of reactor. With the present emphasis on large gas cooled reactors in the UK, the universal value of Mr Rockwell's work depends very much on the confirmation of the above expectation. What then can one say?

It must be stated at once that the whole outlook of the book is coloured by the fact that only relatively small, liquid-cooled, systems are considered. Moreover the obvious necessity in the Naval Programme to minimize weight and volume, with little regard for cost, leads to almost exclusive consideration of iron-water-lead shields. This would detract little from the value of the book, were it not for the fact that experimental evidence is frequently brought forward to back up recommended empirical methods. This experimental evidence is largely confined to iron-water-lead systems, consequently the empirical methods can only be used with confidence within this very limited range.

Apart from this rather severe limitation the work can only be described as an admirable collection of methods and data. As usual in books on shielding, gamma-ray attenuation is described very thoroughly, build-up factors receiving considerable attention; whereas neutron attenuation within the shield is inadequately described. This common fault is of course not due to oversight, but to the difficulties and general lack of data associated with the problem.

Heat generation in the shield is satisfactorily dealt with in principle, but again only water-iron systems are discussed specifically. Chapter 4, on the shielding of the primary cooling system, discusses only liquid coolants. The treatment in this chapter characterises the great emphasis on weight economy, in the exceptionally detailed description of methods of calculation. Also of interest in chapter 4 is the detailed consideration of 0·9 MeV neutrons arising from 4·1 second N^{17}.

Useful chapters describe the principles of shield layout, problems of engineering construction, and the implications of activities after shut-down. An 80-page chapter, though prefaced by a warning of the general inadequacy of the available data, nevertheless gives valuable information on streaming of radiation along straight-through and stepped holes in shields, and on scatter of gamma radiation round the edges of a shield. The last two chapters provide fairly comprehensive data for shielding calculations, including many graphs of commonly occurring geometrical functions.

A second, extended edition is promised within one or two years.

A. J. Joyce

Progress in Nuclear Energy: Series IV. Technology and Engineering. Vol I. Ed. R. Hurst and S. McLain. 6¼in by 9¼in. 420pp + xiii. London 1956: Pergamon Press Price 84s.

The present volume is based mainly on papers given in Vols. 8 and 9 of the Geneva Conference Reports, together with a certain amount of additional material. Papers have been contributed by the atomic energy organizations of France, Canada, Holland, Switzerland, UK, USA, USSR, and Yugoslavia, and these cover such diverse topics as reactor coolants, moderators, heat transfer, reactor chemistry, and corrosion.

In the first chapter, Benedict of the USA gives an excellent survey of heavy water production processes, and discusses in some detail hydrogen and water distillation, electrolysis, and a range of chemical exchange methods. This is followed by a paper from Switzerland which proposes the use of the Kühn multitubular packed column enrichment up to 99·8 per cent D_2O of concentrates from other processes containing upwards of 1 per cent of D_2O. Chapter 2 deals with the subject of moderator graphite, and comprises an extensive paper from members of the staff of the National Carbon Co. of the USA on the production and properties of graphite, together with a short note on graphite production in France. This is followed by a chapter on beryllium oxide, which includes two papers from Saclay dealing respectively with the production and the sintering of this material. A third article discusses comparable Russian work in this field.

Liquid metal technology is discussed at length in Chapter 4, and also in Chapter 5, which is concerned with the engineering aspects of reactor cooling. In the latter chapter the subjects of coolant pumping, of heat transfer to boiling liquids, compressed gases and liquid metals, and of heat conduction in canned fuel rods are considered. In this regard the three papers on liquid metal heat transfer from the USSR, the UK, and the USA are of particular interest, since they show reasonable agreement between the experimental results of a large number of workers, although as yet discrepancies between theory and experiment have not been fully resolved.

The final chapter consists of eight papers dealing with various aspects of the subjects of reactor chemistry and corrosion. These include the radiation chemistry of water, the chemistry of solution and slurry type homogeneous reactors, the aqueous corrosion of aluminium and zirconium alloys, and finally, corrosion by liquid metals.

On the whole, the editors are to be congratulated on their selection and classification of material for this volume, although it would perhaps have been more logical to have included all the papers on liquid metals under a single heading instead of distributing them among three separate chapters. However, detailed criticism of the subject matter could hardly be attempted by a single reviewer in view of the wide range of subjects covered. The format and binding are pleasing and typographical errors appear to be few. There is no doubt that this volume will be much used by technologists in the atomic energy field during the next few years.

H. R. C. Pratt

National Academy of Sciences—National Research Council publications

The NAS has established six committees to investigate the biological effects of atomic radiations from the viewpoint of genetics, pathology, meteorology, oceanography and fisheries, agriculture and food supplies, and the disposal and dispersal of atomic waste. Summary reports of their first technical findings have now been published in a readable book of 108pp called *The biological effects of radiation*. A smaller popular version is also available as is the *Report of the Committee on pathological effects of atomic radiation* (NAS-NCR publication 452). In addition to the sectional reports, this contains a 40-page bibliography dating back to 1903 on the effects of radiation on the blood and blood forming tissues of man. Also published is a report prepared from the transcript of an informal conference held in New York in May 1955 entitled *Basic mechanisms in radiobiology* IV. *Cellular aspects* (NAS-NCR publication 450). The publications are obtainable from: National Academy of Sciences, Research Council, 2101 Constitution Ave, Washington 25, DC.

Economics and Technology for the Atomic Industry (Proceedings of AIF Conference held in Sept 1956 in Chicago). Atomic Industrial Forum Inc., 3 East 54th St, New York 22, NY

Volume I of the 12th in the series of Atomic Industrial Forum Reports is concerned with the Management and Industrial side of the atomic industry. Although this publication is not free from the defects of tautology and recapitulation inherent in American symposium reports, much information may be gained on the problems facing American Atomic Energy and the characteristic direct and energetic steps taken to find solutions to them.

The basic difficulty is caused by the non-competitive nature of atomic power in America and the instinctive abhorrence of State Ownership adds complications.

Unable to rely on the huge assured home market enjoyed by other American industries the atomic industry hopes to surmount its development period building and exporting reactors to countries with high conventional power costs. Even this necessitates a considerable home market and the estimated nuclear power construction in America over the next 20 years is of the same order of size as that in Great Britain.

Although at least one of the projected stations, the Commonwealth Edison boiling reactor, is being financed privately much Government aid will be required and the necessary legislation to place a large programme on a sound footing has so far failed to pass Congress.

The worst problem is insurance. The possible hazard and financial risk arising from a reactor failure is greater than any risk previously insured. The American insurance companies have formed two pools to provide a maximum cover of over 11 million dollars, but this will not include the reactor itself. It is hoped that the bill providing government insurance will be revived and passed.

The field in which the USA have shown perhaps the greatest initiative is in the industrial production of new materials. The method adopted is for the USAEC to award five-year contracts for the supply of such metals as are likely to be required at agreed prices. The possession of this assured market and the generous write-off facilities made possible under American taxation law permits the contracting companies to finance their expansion largely by means of short term bank capital.

American industry—and through them the USA—is placed in a very advantageous position as regards the development and supply of novel materials, and consideration of some mechanism whereby this country's present relatively inferior position could be improved would be advantageous.

L. M. Wyatt

Radioactive Materials and Stable Isotopes Catalogue no 4, Isotope Division, AERE, Harwell; January 1957

A fourth edition of this catalogue of the isotopes on sale from the Isotope Division, AERE, has now been published. The main section, which consists of a table giving the properties and availability of pile-produced radioisotopes, has been increased by nearly forty pages to cover the materials which have become available since the third edition was published in 1954. The section on cyclotron-produced and stable isotopes has also been expanded. Most of the sections have been revised to some extent and some new material has been added. For instance, there is a table of isotopes which have been standardized at AERE by request, and two tables giving beta and gamma energies and half-lives. Also included is a new section describing the facilities for high-intensity ionizing radiations which will be available under the British nuclear programme. A separate catalogue covering naturally radioactive materials, long-lived fission products, labelled compounds and other materials requiring processing or synthesis is available from the Radiochemical Centre, Amersham, Bucks.

PUBLICATIONS

The Tensator Spring. A book of design data for a type of coil spring which exerts a constant force independent of extension. Developed in America as the Neg'ator the device finds wide application in instrument technology. Tensator Ltd, Acton Lane, London NW10

Dorman Long Illustrated 1956 is a bright visual presentation of the firm's activities during the year including the visit of HM the Queen to the new Lackenby works. Dorman, Long & Co Ltd, GPO Box No. 1, Zetland Road, Middlesbrough.

Metropolitan-Vickers Gazette for November contains an article by C. S. Norton on a new industrial radiographic unit. This is the 'Raymax 150' 150kV X-ray machine which is suitable for steels up to about 1½in. thick. Metropolitan-Vickers Electrical Co Ltd, Trafford Park, Manchester 17.

Rhodes, Brydon & Youatt, Ltd, Waterloo Engineering Works, Gorsey Street, Stockport, have issued two new catalogues. No. 1460A fully describes with selection charts, their range of horizontal *Mopumps* for handling chemicals. No. 1506 deals with the new vertical *Mopump* 350 series for high temperature water.

Dewrance & Co Ltd, Gt Dover Street, London SE1, have issued publication 687, describing the *Endewrance* hard-facing welding rods. These are used for applying a specially hard surface to steel surfaces, edges or points which have to resist abrasion, friction, impact, corrosion or heat.

Monsanto Chemicals Ltd, Monsanto House, 10-18 Victoria Street, London SW1 have published their Technical Service Bulletin No. N3 which tabulates the heat transfer data of diphenyl up to 980°F and also lists its physical properties.

Chemical Engineering—A career. An attractive brochure published by the Institution of Chemical Engineers, 16 Belgrave Square, London SW1, designed to appeal to school leavers.

Denis Taylor joins Plessey

NUCLEAR POWER'S Instrumentation Editor, Dr Denis Taylor, Head of the Electronics Division at the Atomic Energy Research Establishment, Harwell has resigned his appointment in the UKAEA and is taking up an appointment in industry. Dr Taylor was one of the first—one might say founder—members of AERE and since the earliest days has played a large part in the building up of the British Nuclear Instruments Industry. His new appointment is as Director and General Manager of Plessey Nucleonics Company Ltd. and he will also act as Research Executive in the Aeronautical and Electronics Groups of the Plessey Company. It is understood that Dr Taylor will not lose his connexion with the UKAEA altogether, as AERE propose to retain his services as a part-time consultant.

Whessoe ready for Bradwell

After an eight-day journey from Staffordshire over a pre-arranged route a huge new charging machine weighing 60 tons arrived at the Whessoe Works in Darlington last month. This Gibbons/Van Marle charging machine was designed and built by Gibbons Brothers Ltd at their Lenches Bridge Works, Pensnett, Staffordshire. Its overall dimensions are approximately 54 ft long by 14 ft wide by 8 ft high.

The machine, together with its propulsion gear and a Gibbons Brothers plate heating furnace, forms part of the extensive equipment Whessoe Ltd is installing for the forming of extra heavy steel plate work. Plates from this furnace will be used on nuclear energy contracts, notably on the nuclear reactor pressure vessels which Whessoe, as a member firm of the Nuclear Power Plant Company, is building for the CEA power station to be built at Bradwell. They will take the form of welded spheres each 66 ft 9 in. in diameter, built of special steel and with a minimum thickness of three inches.

Cape 'Rocksil' for Dounreay

Another furnace for producing *Rocksil* rock wool—a synthetic inorganic fibre for thermal insulation—went into production at the Stirling works of The Cape Asbestos Company Ltd recently. The new furnace took six weeks to dry and to reach the extremely high temperature required to melt the dolomite rock and fireclay which are the main raw materials of *Rocksil*. Said to be the only plant in Britain manufacturing a long-fibre rock wool, the factory was opened in 1954. The raw material—dolomite, or white magnesian limestone—comes from Cape's own quarry in Argyllshire.

One of the largest recent *Rocksil* orders was for the insulation of the fast breeder reactor, and all its auxiliary equipment, including the heat exchanger house, at the AEA's experimental power station at Dounreay.

Dowty's Berkeley contract

As reported in last month's NUCLEAR POWER (p 51), Dowty Nucleonics Limited of Cheltenham are to receive a contract from the AEI—John Thompson organization for the burst slug detection equipment at the CEA's Berkeley power station.

The principle of operation is similar to that employed at Calder Hall, and consists in monitoring continuously samples of the coolant gas from each fuel element channel. The large number of channels to be scanned (3000 in each reactor) has meant the design of a completely pressurized system to route automatically gas samples from every channel to the precipitator units which are located in two rooms for each reactor. It is understood there will be 17 precipitators for each reactor, with 10 more for bulk sampling and spares.

The design has been carried out by a team of specialist engineers at Brockhampton Park, Gloucestershire, and the resources of the Dowty Group will be used for production. It is expected that the equipment will be completed within two years.

Data processing of the counts registered on the Dowty equipment will be done by the Sunvic computer system as described elsewhere in this issue.

This 54ft long charging machine was recently delivered to Whessoe's works at Darlington. It will be used for forming heavy steel plate work for the NPPCo's Bradwell station

IEA Show for 1958 fixed

So great has been the demand for stands and the interest shown throughout industry in the first *Instruments, Electronics and Automation Exhibition*—to be held at Olympia next May 7–17—that it has already been agreed to stage the show again next year. Dates will be April 16-25, 1958, and the location will again be Olympia.

The decision to repeat in 1958 was taken at a meeting on Feb 8 of the organizing committee, representing the five Trade Associations by whom the *IEA Exhibition* is promoted.

When the lists for this year's Exhibition closed, with just on 200 exhibitors, no more space was available in the Grand Hall, Olympia and a waiting list of prospective exhibitors was formed. It was the wish to accommodate, as soon as possible, those who could not be fitted in this time, that influenced the organizing committee to re-stage the show as soon as possible.

B & K hold 3rd Instrument Show

The Third International Instrument Show, sponsored by B & K Laboratories Ltd and Allied International Co Ltd is being staged at Caxton Hall, Westminster, from March 25-29 inc. Over fifty leading instrument manufacturers from the USA, Switzerland, West Germany, Denmark, Holland, Sweden, Austria and Great Britain will be displaying some three hundred items of test equipment and apparatus, a number of which will be demonstrated in typical applications.

Caxton Hall provides double the display area of last year's show, which was

opened in May 1956 by Sir Alan Braithwaite. Many new features are added, and about twenty new exhibitors will be present. Endeavours are being made to secure the personal attendance of factory principals from overseas.

Tickets for the Show, which is open until 6.30 p.m. daily, are obtainable on request from B & K Laboratories Ltd, 57 Union Street, London, SE1—telephone Hop 4567.

Civil Engineers' partnership

Trollope & Colls Ltd and Holland & Hannen and Cubitts Ltd have formed a partnership known as Nuclear Civil Constructors for the purpose of carrying out civil engineering construction for nuclear power stations in association with the fifth atomic contracting group—Atomic Power Constructions Ltd. Nuclear Civil Constructors' address is 54 Warwick Square, London SW1.

In Brief

COOPER & CO (BIRMINGHAM) LTD, felt manufacturers of Brynmawr, Breconshire have acquired the whole share capital of James Farrer & Sons Ltd, Division St, Sheffield, makers of polishing and grinding equipment.

The first sod of the 500-acre site at Tinsley Park, Sheffield for the ENGLISH STEEL CORPORATION LTD's new plant was turned recently by the ESC chairman, Mr F. Pickworth. Buildings alone will cost over £250,000.

CARBIDE INDUSTRIES LTD (a BOC subsidiary) are to build an acetylene plant at Londonderry primarily to supply the neighbouring factory in which neoprene will be manufactured by DU PONT (UK) LTD.

MIDLAND SILICONES LTD have moved their North Eastern Area Sales office to: 5/7 New York Rd, Leeds 2 (tel: Leeds 26768). Area manager is Mr R. Nattrass. CHEMIDUS PLASTICS LTD, have moved their Administrative and Sales Office to: Dominion Buildings, South Place, London EC2 (tel: Monarch 0131).

NAMES IN THE NEWS

The appointment is announced of **Mr C. H. Flurscheim** as Chief Electrical Engineer of Metropolitan-Vickers Electrical Co Ltd in succession to Mr Harry West who will be able to devote more time to the affairs of AEI-John Thompson Nuclear Energy Co. Mr West retains his seat on the board of MetVic.

British Insulated Callender's Cables Ltd chairman and managing director **Mr W. H. McFadzean** is on a world tour of BICC organizations and is due back towards the end of this month.

Mr K. W. Trevatt has been made a representative of the Cambridge Instrument Co Ltd in the Liverpool area in succession to **Mr W. J. Cole** who has retired from this post after 27 years. **Mr R. Watkins** has been appointed Scottish representative for new instruments.

Ekco Electronics Ltd have appointed **Mr A. H. Johnston** as nucleonics sales engineer for the north of England.

Mr A. E. Grimsdale is appointed manager, home sales, of Metropolitan-Vickers Electrical Co Ltd. He has been with MetVic since 1922.

Mr W. R. Edwards has retired from his post as Managing Director of John Thompson Water Tube Boilers Ltd and is succeeded by **Mr C. J. Howard.** Mr Edwards will continue with the John Thompson Group in a consultative capacity.

Mr J. F. Hendrie has been appointed sales manager of the Nucleonic and Electronic Department of Dynatron Radio Ltd.

Mr Bruce Wilkinson has joined The Plessey Co Ltd as divisional manager of the Swindon Components Division. Mr Wilkinson was formerly managing director of Electronic Tubes Ltd.

E. K. Cole Ltd have appointed **Mr J. E. Furley** as publicity manager. Mr Furley has been with Ekco since 1932.

Mr D. S. Howarth has been appointed manager, stationary battery sales, for Chloride Batteries Ltd. **Mr S. H. Chase** has retired after thirty-three years service. Brush Electrical Engineering Co Ltd have appointed **Mr R. A. Grierson** manager of the transformer division.

W. P. Butterfield Ltd have appointed **Mr John Eden** as contracts manager.

Mr C. T. Alderson has joined the board of Ruston & Hornsby Ltd.

Mr W. J. Vaughan has been made technical sales representative for north-east England of Newall Group Sales Ltd.

Lord Bicester has been made a director of Associated Electrical Industries Ltd.

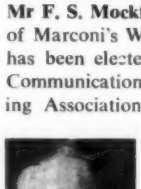
Mr Frank Clark, well-known for his work on welding, has been appointed manager of the sales technical service department of British Oxygen Gases at Cricklewood.

Mr F. E. Barritt, Works manager, and **Mr L. R. Pullen,** sales manager, have been appointed directors of K.D.G. Instruments Ltd.

Sangamo Weston Ltd announce that **Mr M. G. McBride** has rejoined the company as contracts manager of the Instrument Division. Before leaving in 1952 Mr McBride was employed in the Engineering Department.

Mr David A. Pitman has been elected a director of Electronic Instruments Ltd. In his position of sales director he will be responsible for coordinating the sales activities of both home and overseas branches of EIL.

Mr J. E. C. Bailey, chairman and managing director of Baird & Tatlock (London) Ltd, Hopkin & Williams Ltd, and W. B. Nicolson (Scientific Instruments) Ltd is at present on a short tour of Africa to discuss with representatives the export of scientific equipment and chemicals.



Lieut Cdr D. A. Pask has joined the CEA's Nuclear Power Branch as Construction engineer. Mr Pask was deputy resident engineer for the construction of Calder Hall.

Mr F. S. Mockford, commercial manager of Marconi's Wireless Telegraph Co Ltd, has been elected chairman of the Radio Communication and Electronic Engineering Association (RCEEA).

The CEA have appointed **Mr D. P. Sayers** as chief contracts officer in succession to Mr F. W. Smith who retired at the end of last year.

Mr S. F. Steward has been appointed chairman of Lancashire Dynamo Holdings Ltd in succession to Lord Mills, who resigned on becoming Minister of Power.

Mr H. F. Bibby and **Mr G. H. Jolley** have joined the board of Metropolitan-Vickers Export Co Ltd.

IC's Jubilee

The Imperial College of Science and Technology celebrates this year the Jubilee of its establishment by Royal Charter in 1907. The celebrations will include a visit on May 28 of Queen Elizabeth The Queen Mother, Chancellor of London University, during which Her Majesty will open the Roderic Hill building for Aeronautics and Chemical Engineering. The Marquess of Salisbury, Lord President of the Council, is to be the guest of honour at the Jubilee dinner to be held at the Mansion House on May 27.

RCEEA and data processing

The Council of the Radio Communication and Electronic Engineering Association has approved the formation of a Data Processing Section. This followed the recommendations of a meeting of representatives of ten member-firms of the Association. Chairman of the section is Mr C. Metcalfe, managing director of EMI Electronics Ltd, and a Data Processing Technical Sub-Committee has been formed.

The new section is intended to serve the interests of the many firms who are concerned in the new field of electronic computer equipment both digital and analogue, and also the manufacturers of input and output devices and allied equipment.

It is believed that the work of the section will be of interest to a number of manufacturers not at present members of the Association and applications for membership of the Data Processing Section only are being invited.

Eastbourne venue for BEPC

Electricity in the National Economy, has been chosen as the theme of the 9th British Electrical Power Convention, to be held this year at Eastbourne from June 17 to 21, under the Presidency of Sir Josiah Eccles, Deputy Chairman (Operations) of the CEA. As in previous years, an exhibition will be held in conjunction.

Among the Convention's seventeen papers will be *Nuclear Energy in Great Britain* by J. C. Duckworth, Deputy Chief Engineer (Nuclear Power), CEA, and W. H. C. Pilling, Project Engineer, also of the CEA. They will show, in a not-too-technical way, the rapid progress which has been made in this country and will indicate some of the future possibilities. It will be read on the afternoon of June 19.

The Convention papers have been prepared against the background of the national economic situation. In addition to revealing to the general public the great contribution made by the electrical industry to their well-being, they will also demonstrate to the world that Great Britain is in the forefront in the development and utilization of electrical energy, including atomic energy, for the benefit of mankind.

The Annual Dinner will be held at the Grand Hotel on the Thursday evening, and this will be followed by a Dance at the Winter Garden.

BS for asbestos fibre jointing

The British Standards Institution have issued BS2815:1957 *compressed asbestos fibre jointing*. This deals with two grades: *GRADE A*. For use with water, inert gases, inert liquids or steam up to 950 lb/sq. in. and 950°F. *GRADE B*. For use with water, inert gases, inert liquids or steam up to 250 lb/sq.in. and 450°F.

New SIMA show

The 4th display of instruments organized by the Scientific Instrument Manufacturers' Association was recently opened at SIMA House, 20 Queen Anne Street, London W1. The following members are showing a selection of their latest products: Advance Components Ltd, British American Optical Co, Chance Brothers Ltd, Edwards High Vacuum Ltd, Ekco Electronics Ltd, Electronic Instruments Ltd, Ellis Optical Company, Foster Instrument Co Ltd, A. Gallenkamp & Co Ltd, Hendrey Relays Ltd, Hilger & Watts Ltd, Marconi Instruments Ltd, L. Oertling Ltd, W. F. Stanley & Co Ltd, H. W. Sullivan Ltd, and Unican Instruments Ltd. The exhibition will be open until the beginning of April.

Electricity key to prosperity

"The amount of electricity consumed per head of the population is today a measure of the prosperity of a country." This was stated by Mr L. Landon Goodman, of the Electrical Development Association, speaking in Dublin last month at the opening of a five-day *Electricity and Productivity Conference and Exhibition* organized by the Electricity Supply Board, Ireland.

Mr. Landon Goodman said that the relative cost of a horse-power hour of human energy / animal energy / electric energy was in the ratio of approximately 480/30/1. This ratio was the key to higher productivity and prosperity. The average man could exert not more than 1/10th or 1/20th of a horsepower over a period of time; consequently to put even a one horse-power motor at his disposal was to give him ten or twenty electrical slaves to work for him. With this in mind, the improved output resulting from the installation of a simple electric pulley block, small belt conveyor or battery-electric truck could readily be seen. The application of electricity in industry had wide repercussions throughout a production process. It was necessary to plan carefully the applications of electrical methods if the fullest advantages were to be obtained from them.

Civils new President

Following the death of President H. J. F. Gourley, The Institution of Civil Engineers have elected senior Vice-President Sir Arthur Whitaker, KCB, MEng, MICE, as President for the remainder of the year.

Sir Arthur was for many years Civil Engineer-in-Chief, Admiralty, and is now a partner in the firm of Livesey & Henderson, Consulting Engineers. He was born in 1893, and educated at Liverpool Institute High School, and at Liverpool University.

Solid State Physics Conference

A conference on *Physics of the Solid State*, organized by Professor L. B. Bates, FRS, will be held on April 8-10 in the Physics Department, University of Nottingham. Contributors will be drawn from Universities and Research Establishments.

On Tuesday, April 9, Professor H. C. Urey, Enrico Fermi Institute for Nuclear Studies, the University of Chicago, will deliver the Physical Society's *Guthrie Lecture* at Nottingham University. The subject will be *Some Chemical Limitations on Theories for the Origin of the Solar System*.

Non-members are welcome to attend this meeting on payment of a Conference Fee of 10s. Accommodation will also be available.

Further details from: The Physical Society, 1 Lowther Gardens, Prince Consort Road, London SW7 (attention: Miss Miles).

Lord Mills

In the news of Lord Mills' appointment as Minister of Power (NP 2 10 p 39) it was stated that he was Chairman of the National Research Development Corporation. We are informed that Lord Mills resigned this post in 1955 and was succeeded by Sir Alan Saunders OBE.

RESEARCH REPORTS

United Kingdom

*The following reports have been made available to the public by the United Kingdom Atomic Energy Authority. They may be borrowed or photocopies obtained from the Science Library, London, Department of Industrial and Forensic Science, Belfast, the Mitchell Library, Glasgow, and the Central Libraries at Acton, Birmingham, Bristol, Kingston-upon-Hull, Leeds, Liverpool, Manchester, Newcastle-upon-Tyne and Sheffield. They are also deposited in the Copyright Libraries (i.e. British Museum; University Library, Cambridge; Radcliffe Science Library, Oxford; National Library of Scotland, Edinburgh; National Library of Wales, Aberystwyth) and in the Patent Office Library. Reports marked * may be purchased from Her Majesty's Stationery Office.*

Reports are also available in the United States, from the USAEC depository libraries, a list of which will be found in NUCLEAR SCIENCE ABSTRACTS. Reports for sale may be purchased in the United States from: Sales Section, British Information Services, 30 Rockefeller Plaza, New York 20, N.Y.

Atomic Energy Research Estabt.

Non-resonant coupling of resonant cavities. P. D. Dunn, R. J. B. Hadden, D. J. Thompson. (Oct 1956, 24 pp) 3s. 6d. AERE GP/R 1962*

A test pulse generator for use with the Harwell 15 MeV linear accelerator and the associated neutron time-of-flight equipment. F. W. K. Firk (Sept 26, 1956. 21 pp) AERE NP/R 2043

Measurements of the change in cross section of irradiated uranium made by modulating the power of a nuclear reactor. A thesis submitted for the degree of Doctor of Philosophy in the University of London, 1956 D. J. Littler (Nov 6, 1956. 92 pp) AERE RS/R 2092

Notes on some binary systems containing uranium trifluoride. R. W. M. D'Eye, F. S. Martin (Nov 19, 1956. 4 pp) 1s. AERE C/M 292*

Industrial Group

The gravimetric determination of plutonium as oxide at 1250°C. (Dec 18, 1956. 3 pp) IGO-AM/W 64

Formation and disproportionation of intermediate uranium fluorides. V. Y. Labaton. (Oct 3, 1956. 17 pp) IGR-R/CA 193

Hydrogen solubility in metals. B. Yates. (Nov 1956. 32 pp) IGRL-IB/R 17

Canada

The following reports may be obtained from: Scientific Document Distribution Office, Atomic Energy of Canada Limited, Chalk River, Ontario. Remittances should accompany the order and should be in the form of cash, bank or express postal money orders or cheques made payable in Canadian funds at par in Chalk River to Atomic Energy of Canada Limited.

The determination of the D_2O content of heavy water by infra-red spectrometry. W. H. Stevens, W. Thurston. (1954 now reprinted. 24 pp) $1.00. AECL 295, CRC-598

The separation of hafnium and zirconium by ion exchange. R. E. Cooper, Miss R. M. Dinzey. (1950 now reprinted. 24 pp) $1.00. AECL 299, CRCE-466

The extraction of plutonium from plutonium-aluminium alloys by molten bismuth. D. E. McKenzie, J. W. Fletcher, T. Bruce. (1956. 12 pp) 50c. AECL 314, CRC-639

The stripping of oxygen from solution by a partial flash vaporization. D. H. Charlesworth. (1955 now reprinted. 18 pp) 50c. AECL 315, CRCE-607

Heavy water production by natural water distillation I., General considerations. H. K. Rae. (1954 now reprinted. 31 pp) $1.00. AECL 322, CEI-73

Heavy water production by natural water distillation II., Preliminary cost estimate. H. K. Rae, A. H. Stenning. 1954 now reprinted. 54 pp) $1.50. AECL 323, CEI-74

Thermal conductivity of metals at high temperatures II. Thermal conductivity of uranium: a preliminary study. J. D. Babbit, T. M. Dauphinee, L. D. Armstrong, W. Peria. (1949 now reprinted. 37 pp) $1.00. AECL 326, CRR-438

Five figure tables for the conversion of electron momentum to electron kinetic energy from 100 to 20000 Gauss-CM. J. L. Wolfson, H. S. Gellman. (1954 now reprinted. 43 pp) $1.00. AECL 327, PD-255

Proceedings of the symposium on the physics of fission held at Chalk River, Ontario. May 14-18, 1956. G. C. Hanna et al. (1956. 414 pp) $5.00. AECL 329, CRP-642-A

The calculation of line shapes in ungridded ionization chambers. J. C. D. Milton, Anne R. Rutledge, Patricia I. K. Lennox. (1956. 65 pp) $1.50. AECL 331, CRP-632

Determination of neutron flux by measurement of captive gamma rays A. W. Boyd, J. L. Whitton. (1956, 9 pp) 50c. AECL 332, CRDC-637

Elementary approximations in the theory of neutron diffusion. P. R. Wallace, J. LeCaine. (1943 now reprinted, 172 pp) $3.00. AECL 336, MT-12

A table of Levy's empirical atomic masses. J. Riddell. (1956. 90 pp) $2.00. AECL 339, CRP-654

Nuclear reactions in stars and nucleogenesis. A. G. W. Cameron. (1956. 30 pp) $1.00. AECL 340, CRP-652

Progress report—Physics Division—April 1 to June 30, 1956. L. G. Elliott et al. (1956. 77 pp) $2.00. AECL 343, PR-P-30

Report on waste disposal system at the Chalk River Plant of Atomic Energy of Canada Ltd. C. A. Mawson. (1956. 15 pp) 50c. AECL 344, CRB-658

The problem of flux instability in large power reactors. A. G. Ward. (1956. 10 pp) 50c. AECL 345, CRRP-657

Calculated cross sections of irradiated fission products. D. G. Hurst. (1956. 9 pp) 50c. AECL 346, CRRP-659

Effect of flux flattening on pile power. M. F. Duret, W. J. Henderson. (1956. 22 pp) 50c. AECL 347, CRRP-656

Tributyl phosphate processing of Pu-Al alloy fuels preliminary investigation. P. D. Goulden, R. W. Durham, V. Corriveau. (1955. 20 pp) 50c. AECL 348, CRDC-640

Design of a head and keyed closure for a nuclear reactor pressure vessel. W. H. Bowes. (1956. 34 pp) $1.00. AECL 349, NPG-9

Comparison of theory and experiment for (a) lattice properties of D_2O-U reactors (b) central rod experiments (c) foreign rod experiments. E. Critoph, A. G. Ward. (1956. 63 pp) $1.50. AECL 350, CRRP-655

The specification of neutron flux and effective cross sections in reactor calculations. C. H. Westcott. (1956. 11 pp) 50c. AECL 352, CRRP-662

A batch process for the recovery of AM^{241} from kilogram amounts of plutonium. J. P. Butler, Mrs. J. S. Merritt. (1956. 25 pp) $1.00. AECL 353, CRC-661

Radiation monitoring of NRU. W. J. Henderson. (1956. 7 pp) 20c. AECL 363, CRRP-669

Calculated cross sections of irradiated thorium (revised). D. G. Hurst. (1956. 16 pp) 50c. AECL 364, CRRP-667

PROGRAMME

ICE Institution of Civil Engineers. IMechE Institution of Mechanical Engineers. IEE Institution of Electrical Engineers. IChemE Institution of Chemical Engineers. IP Institute of Physics. PS Physical Society. SCI Society of Chemical Industry. IM Institute of Metals. IMet Institution of Metallurgists. IMM Institution of Mining and Metallurgy. IPE Incorporated Plant Engineers. SIT Society of Instrument Technology.

MARCH

Tuesday 5

LONDON ICE **Behaviour of radioisotopes in sewage treatment and the disposal of radioactive waste to sewers** A. W. Kenny. 5.30 at the Institution

Wednesday 6

BIRMINGHAM IChemE **Project costing in the chemical industry** B. M. Robbins, H. C. Hollands. 6.30 at Midlands Institute, Paradise Street

Tuesday 12

LONDON IEE (BNEC) **An analogue computer for nuclear power studies** and **The application of analogue methods to compute and predict xenon poisoning in a high flux nuclear reactor** G. J. R. MacLusky. 5.30 at The Institution

Thursday 14

MANCHESTER IChemE **Disposal of long-lived fission products** J. R. Grover. 7.00 at the College of Technology

Wednesday 20

LEEDS IChemE **A study of the motion of the solid phase in liquid fluidized beds** N. C. Franklin, D. Hardley. 7.00 at the University

Thursday 21

CHESTER IPE **Welding and testing welds by X-ray** R. B. Whalley. 7.15 Stafford Hotel, City Road

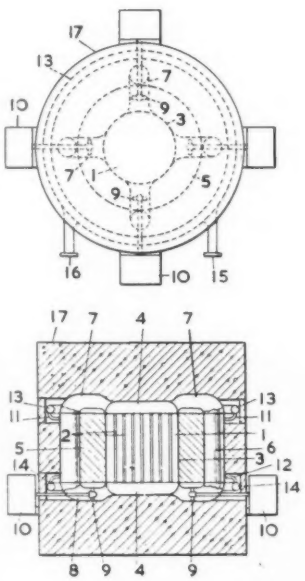
LONDON IMM **Separation of uranium and copper during the acid pressure leaching of sulphidic uranium ores** J. Halpern and F. A. Forward. **Hydrometallurgical processes at high temperatures** F. A. Forward, J. Halpern. Geological Society, Burlington House, W1 at 5.00

Tuesday 26

LONDON SIT **Process development and plant design—the role of instrumentation with particular reference to the application of computers** S. T. Lunt. 7.00 at Manson House, Portland Place, W1

763,231 **Improvements in or relating to nuclear power units.** United Kingdom Atomic Energy Authority (Inventors: S. G. Bauer and C. D. Boadle). App: Jan 22, 1952. Pubd: Dec 12, 1956

In a liquid-metal-fuelled reactor, a possible disadvantage is the high hold-up in the heat exchanger compared with the core. In this invention, an intermediate heat exchanger circuit is introduced between the primary fluid and working fluid. This also provides a buffer against contamination of the working fluid in the event of a leak. The specification describes an example as follows: The moderator is a beryllia cylinder 148cm dia. and the same height pierced by holes through which the fissionable material flows. The core is enclosed in austenitic steel drum and around this is a partial reflector of graphite, beryllia or water. Four shell-and-tube heat exchangers are arranged radially, communicating with the top and bottom headers on the core tank, circulating pumps being located in the lower connexions. Secondary connexions to the primary heat exchangers are taken from a ring main. The primary circuit is filled with 1·05 per cent solution of U-235 in 6 tons of molten lead, the weight of U being 20kg. The secondary circuit contains sodium. This arrangement is estimated to provide 100MW heat at a sodium outlet temperature of 600°C. The flow rate for the primary circulation pumps would be about 248 l/sec. The whole active part would be embedded in a dense concrete shield.



763,231 A LIQUID-METAL-FUELLED REACTOR

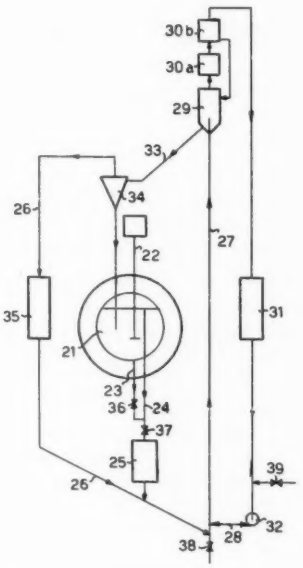
1 beryllia core	10 pump motors
2 flow channels	11, 12 secondary flow and return
3 core drum	13, 14 ring mains
4 headers	15, 16 inlet and outlet branches to secondary circuit
5 reflector	17 shield
6 heat exchangers	
7 flow to h.e.	
8 return	
9 pumps	

763,350 **Improvements in or relating to the purification of metals.** The General Electric Co Ltd and C. H. L. Goodman. App: Nov 23, 1953. Pubd: Dec 12, 1956

Fractionating fusion may be used to purify metals which have become contaminated after irradiation due to their use as fuels or coolants. By this is meant a process which moves a molten zone through the metal. One arrangement of the process is for purifying U bars after use as a reactor fuel. The ingot is placed in a horizontal refractory trough and moved through a furnace in a way that a molten zone is created at one end and caused to travel along the bar. The solid parts on each side of the molten zone may be cooled and the liquid metal in the zone may be mixed mechanically or ultrasonically. By this means, impurities which are more soluble in molten uranium than in liquid uranium are concentrated at the end which is molten first and vice versa. After the process has been repeated the required number of times, the impurities are concentrated at the ends, leaving the centre parts of the bar in a purer state. The principle may be adopted for other metals and it is also claimed to be suitable for remote operation.

755,015 **Process of nuclear fission.** Stichting voor Fundamenteel Onderzoek der Materie, Utrecht. App: (UK) Nov 22, 1954. Pubd: Sept 12, 1956

A reactor is described in which the fuel is a suspension of fissionable material in a liquid which may serve a moderator, coolant or both. A separate moderator may also be included in suspension. One difficulty with this type of arrangement is that owing to the high concentrations of solids required, the slurry is difficult to pump. Fission products, too, are hard to separate. In this invention, the suspension is diluted outside the reactor vessel with additional carrier fluid which is separated again by hydrocyclone thickener before the next entry. Continuous removal of fission products may also be done from the dilution liquid. Circulation of the dilute solution would be a gas riser, the gas being continuously separated and recirculated. This also removes gaseous fission products.



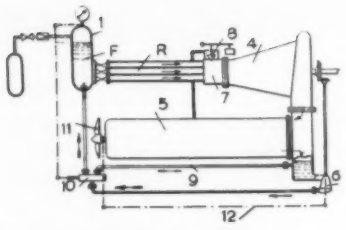
755,015 A HOMOGENEOUS REACTOR

21 reactor vessel	30b water separator
22 vibrostirrer	31 gaseous fission product removal
25 heat exchanger	
26 dilution line	32 gas pump
27 riser	34 hydrocylone thickener
29 gas separator	
30a catalytic recombiner	35 solid fission product removal

754,559 **Improvements in thermal nuclear reactors, in particular for aircraft propulsion** H. P. G. A. R. von Zborowski. App: March 26, 1954. Pat: Aug 8, 1956

The reactor is a thermal one and in its simplest form consists of a tube of fissionable material with a mass slightly over critical. The moderator suggested is D_2O, H_2O, hydrocarbons or water-alcohol mixture. It is supplied to the top end of the tube in gaseous form at a low pressure and as the pressure rises the density also rises, thus increasing the moderating effect. Control of reactivity is achieved by regulating the mass flow of the moderator and automatic stability is claimed since any accidental increase in heat output results in a lower density and hence a lower moderating power.

A number of these tubes may be used to constitute a reactor and it is suggested that they be polygonal in cross section and so fit closely together. Other forms are also described. On an aircraft appli-



754,559 A TURBINE APPLICATION

F moderator fluid
R tubes of fissionable material
1 reservoir
4 turbine
5 condenser
6 pump
7 Pressure equalizing chamber
8 safety valve
9 bypass
10 regulator
11 condenser cooling fans driven through 12

cation, the efflux may be used directly to obtain jet thrust or it may be used to drive a turbine, either on open or closed circuit.

763,865 **Improvements in or relating to production of radioactive iodine-131.** The United Kingdom Atomic Energy Authority (Inventors: C. C. Evans and J. Stevenson). App: Sept 27, 1952. Pubd: Dec 19, 1956

The process is Te^{130} (n, β) I^{131}. Te irradiated with thermal neutrons is heated to a temperature above the boiling point of iodine to distill off I^{131} which may be collected preferably in aqueous caustic alkali. In detail, precipitated tellurium dioxide in a closed silica container is irradiated in a flux of about 10^{12} for 10 days. The container is then put into another silica container in an electric furnace and an outlet arranged to a train of bubblers containing 0·14N aqueous caustic soda and a further tube admitted allowing a continuous slow stream of oxygen. The substance is heated to 650-700°C and the iodine driven off is collected in the bubbler. The heating takes about 24 hours at the end of which the contents of the bubbler are treated with SO_2 and diluted with water to give the desired concentration.

765,489 **Improvements in or relating to production of radioactive phosphorus.** The United Kingdom Atomic Energy Authority. App: Sept 25, 1954. Pubd: Jan 9, 1957

Previous methods of separating radioactive phosphorus from neutron-irradiated sulphur have involved a solvent extraction step. This method is claimed to be much simpler and is essentially done in one step. It is suitable for automatic control, is dry—giving rise to no active effluent, and is such that the sulphur may be recycled. The P-containing S is distilled to remove the S and the residue is taken up with a mineral acid. This contains an oxidizing agent — *e.g.* hydrogen peroxide — to remove any traces of organic matter present. Distillation is done in an inert atmosphere. Condensed S may be irradiated again. Irradiation time is 28 days in 10^{12}. Separation of radioactive phosphorus is claimed to be 99·9 per cent.

765,924 **Improvements in or relating to methods of separating plutonium.** The United Kingdom Atomic Energy Authority. App: Jan 25, 1946 (in Canada). Pubd: Jan 16, 1957

In an irradiated uranium fuel rod, the weight of fission products may be of the order of 10g depending on the degree of irradiation. The irradiated bar is first dissolved in nitric acid. Bismuth nitrate and zirconium nitrate are then added to the solution as carrier compounds, and insoluble phosphates of plutonium, zirconium, bismuth and niobium are precipitated from the solution by adding an aqueous solution of a soluble phosphate. The mixed phosphate precipitate is first leached with dilute hydrochloric acid to dissolve bismuth phosphate and the insoluble residue is leached with hydrochloric acid to dissolve plutonium phosphate. The process is described by an example.

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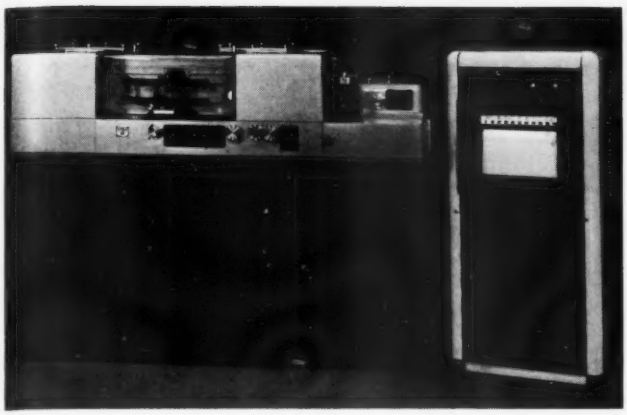

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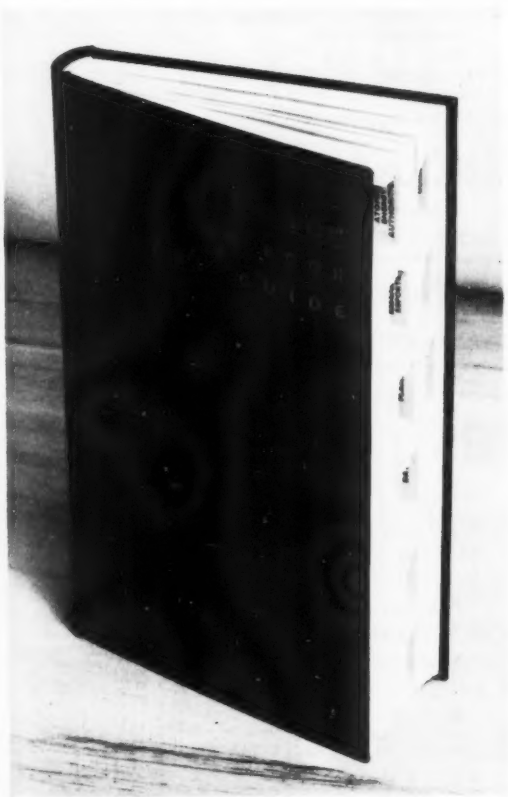

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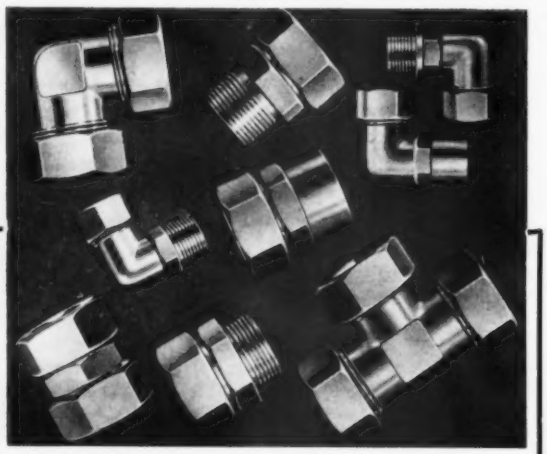

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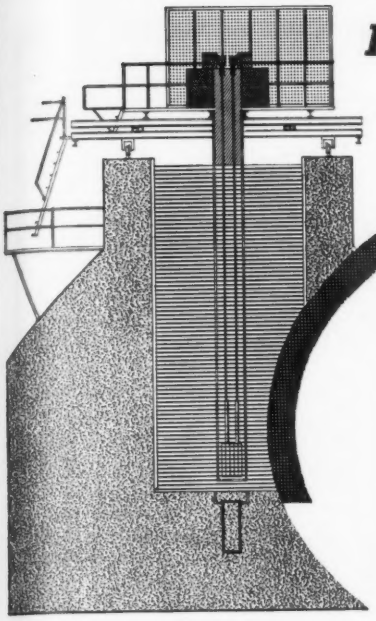
REACTOR INSTRUMENTATION



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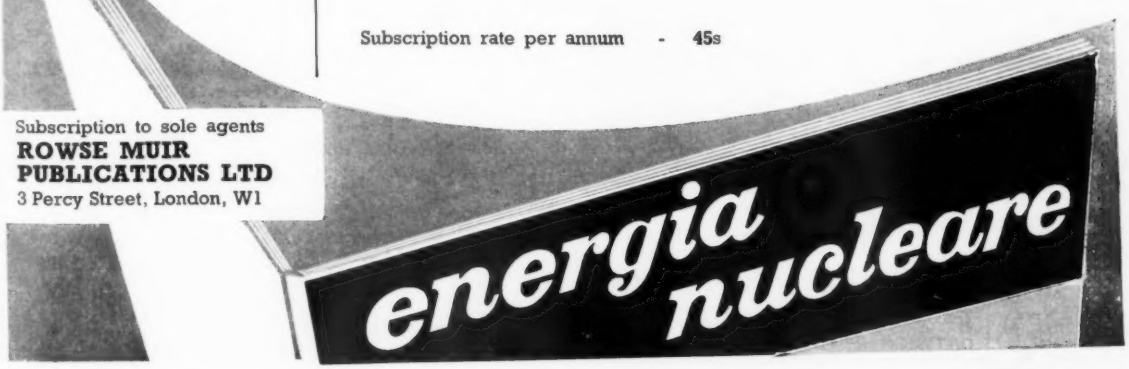

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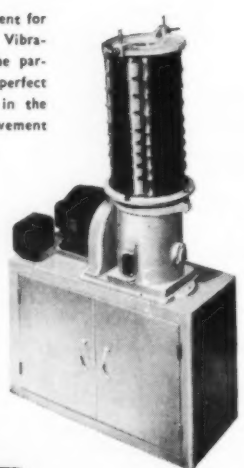

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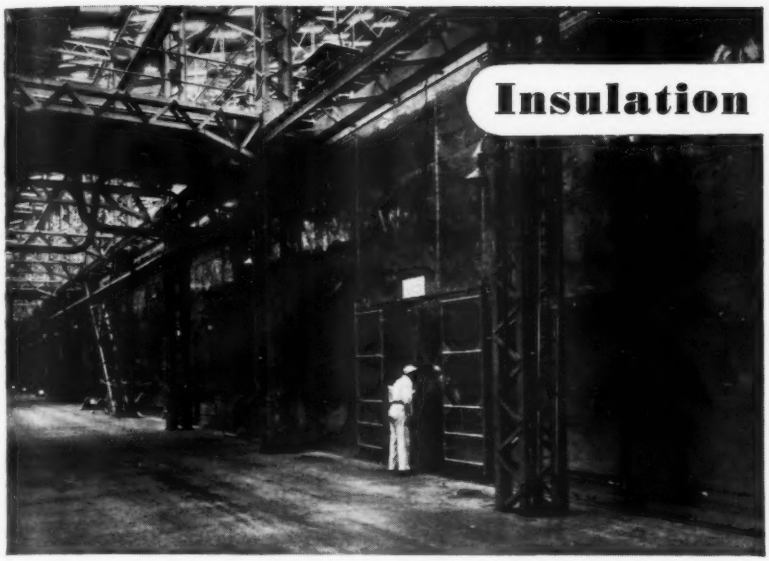

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A. Commercial Department (Reference No. 1745):
The duties will be concerned with the exploitation of technological information and sales of materials, particularly nuclear fuel, by the Authority, both in the United Kingdom and Overseas. There will also be opportunities for working in collaboration with British industry and the Electricity Supply Authorities in the development of industrial applications of atomic energy.
A sound technical/commercial background is called for with the ability to appreciate the commercial value of technological development work. Candidates should have had previous experience of (a) high-level industrial negotiations and the drawing up of commercial agreements and/or sales contracts, and/or (b) working in close liaison with the Research Engineering and Production Departments of a major industrial concern.
Selected candidates will be given facilities to acquire an understanding of the technical processes and plants of the Industrial Group.
B. Overseas Department (Reference No. 1747):
The responsibilities will cover a wide range of duties, including negotiations with foreign government departments and industrial concerns: the implementation of international agreements on the peaceful use of atomic energy and attendance at international conferences. In the technical field all aspects of atomic power generation will be covered, including design and construction of power reactors and chemical plants, together with design and fabrication of fuel elements.
Preference will be given to candidates in their early thirties with a background of technical achievement and ability to appreciate detail rapidly. Previous experience of overseas liaison and a knowledge of economics will be an advantage.
Qualifications: Candidates for all posts should possess a Degree in one of the Applied Sciences and/or be Corporate Members of one of the Senior Professional Institutions.
Salaries: will be assessed within the following scales:—Grade I, £1705–£1980; Grade II, £1235–£1655 per annum.
A contributory pension scheme is in operation.
Authority houses for renting by successful married candidates may be available in due course, or, alternatively, substantial assistance may be given towards legal expenses incurred in private purchase.
Send a postcard asking for an application form and quoting appropriate reference number, to The Recruitment Officer, United Kingdom Atomic Energy Authority, Industrial Group Headquarters, Risley, Warrington, Lancs.
Closing date, March 4th, 1957.

REACTOR PHYSICS

A Physicist is required for training in the field of Nuclear Reactors. The age limits for the post are from 21-26. The minimum qualifications required are a good Honours Degree or its equivalent. A background of experimental or theoretical nuclear physics would be an advantage.

The final position will be with the A.E.I.-John Thompson Nuclear Energy Co. at Radbroke Hall, Knutsford.

Training will involve secondment to the A.E.I. Research Laboratory and at A.E.R.E., Harwell, for a period of up to two years.

After the initial training at Aldermaston and Harwell, the work will be with one of the largest nuclear power firms in the United Kingdom. It will involve theoretical and/or experimental problems in research and/or reactor design.

Radbroke Hall is situated in very pleasant country and close association is kept with other members of the A.E.I. and John Thompson groups at Aldermaston, Harlow, Manchester, Rugby and Wolverhampton.

Applicants should send details of their previous career to the Personnel Officer, quoting Reference No. N/R/G/JT.

Research Laboratory,
ASSOCIATED ELECTRICAL INDUSTRIES LIMITED,
Aldermaston Court,
Aldermaston, Berkshire.

ATOMIC ENERGY RESEARCH ESTABLISHMENT, Harwell, has a vacancy in the Tandem Generator Group of the General Physics Division for an Experimental Officer experienced in Electronics. The requirement in the first place is experience in construction and maintenance of routine control equipment; amplifiers, stabilizers and servo systems of various types. The construction work will also include the electronics associated with the ion sources. The work will include, at a later date, assistance with electronic apparatus associated with nuclear physics experiments.

Salary (male) £940—£1,155 (Experimental Officer). Minimum age 26.

Send POST CARD for further details and application form, which must be returned by March 7th, to Establishment Officer, A.E.R.E., Harwell, Didcot, Berks, quoting reference 730/215.

ATOMIC ENERGY RESEARCH ESTABLISHMENT

requires—FOREMAN IN CHARGE of the ELECTRONICS PRODUCTION UNIT at BRACKNELL to supervise, control and train staff in small production runs of Electronic Instruments.

Apprenticeship or equivalent training in Electronics (e.g. Radar or pulsed Circuits). Practical and supervisory experience in production and testing of electronic equipments, preferable instrumentation for radioactivity measurements and nuclear research. H.N.C. an advantage.

Starting Salary £795 (age 30) or £965 according to qualifications and experience.

Send POSTCARD for further details, and an application form to be returned to Establishment Officer, A.E.R.E., Harwell, Didcot, Berks, by 12th March, 1957, quoting reference 720/202.

UNIVERSITY OF CAMBRIDGE, DEPARTMENT OF ENGINEERING. POST-GRADUATE COURSE IN CONTROL ENGINEERING.

The 1957-58 POST - GRADUATE COURSE in CONTROL ENGINEERING will be held in the Department of Engineering, Cambridge University, beginning on October 9th, 1957, and lasting approximately nine months. This is the second Course of a series which has been established in order to meet the need of certain sections of industry for men trained to a high standard in the theoretical principles and practical application of automatic control, and to afford opportunity for study of advanced techniques and modern development in the general field of control engineering.

The number of students will be limited and applications must reach the Secretary of the Engineering Laboratory not later than July 1st, 1957. Candidates should hold a Degree in Engineering or a suitable alternative qualification, and have had some practical training and experience. They will be required to attend for interview in Cambridge in July or August.

Further details and forms of application for admission may be obtained from the Secretary, Cambridge University Engineering Laboratory, Trumpington Street, Cambridge.

SITUATIONS VACANT

RICHARDSONS, WESTGARTH and CO LTD, has the following vacancies at its Head Office, Northumberland Engine Works, Wallsend, in connexion with development work and contracts arising from new projects:—

ASSISTANT ENGINEERS

For design and development work on new projects in the mechanical engineering field. Large scope for imagination and initiative. Engineering Degree or H.N.C.

DESIGN AND DETAIL DRAUGHTSMEN

Trained to H.N.C. standard, with good drawing-office experience for work in an expanding development department covering a large number of activities. No separate detail D.O.

The vacant positions offer scope for promotion and advancement, in addition to good initial remuneration, pension scheme, etc.

Applications, which will be treated in strict confidence, should be addressed to the Group Personnel Officer, Richardsons, Westgarth and Co Ltd, P.O. Box 2, Wallsend-on-Tyne.

ELECTRONIC ENGINEERS and PHYSICISTS required by Ministry of Supply Research and Development Establishments chiefly at Malvern, Worcs, Farnborough, Hants, Sevenoaks, Kent. Candidates should have or be obtaining 1st- or 2nd-class honours degree or equivalent with experience or interest in Radio, Radar and Communications; instrumentation for telemetry and other measurements; electronic devices; application of advanced techniques to other fields, e.g. armament. Appointments initially in grade of Scientific Officer (min. age 21) with salary according to research experience, etc., in range £565—£995 p.a. (Superannuable). Forms from M.L.N.S., Technical and Scientific Register (K), 26 King Street, London SW1, quoting D 514/6A.

HEAT TRANSFER AND FLUID FLOW—RESEARCH AND DEVELOPMENT ENGINEER required by an old-established engineering company in the Glasgow area. Applicants, aged 25-30, should have a University Honours Degree in Engineering and some research experience. The work would involve the theoretical design and practical testing of new types of heat exchanger. A good salary would be paid to an applicant with the necessary qualifications. Apply, giving age and full particulars, Nuclear Power, Box 3/1609.

SUB-CONTRACTING — CAPACITY AVAILABLE for Plate and Sheet Metal Fabrication, General Machining and Erection. Special Machines and Prototypes to Customers' designs. Hobbs, Hart and Co Ltd (Telephone Leytonstone 1034).

PRECISION ENGINEERS — Personal service for prototypes, small quantity machined parts and equipments. Design and development undertaken. A.I.D. Approved. Bowyer, Smyth and Partners, Ltd, Vineyard Walk, Clerkenwell, E.C.1 ('phone, TERminus 5113–4).

PUBLICATIONS

THE NUCLEAR POWER YEAR BOOK and BUYERS GUIDE has been in preparation for over 9 months and will be published shortly. Copies can be ordered in advance, UK: price 42/- plus 1/- postage and packing. Overseas: price 63/- plus 1/6 postage and packing. US, Canada: price $8 plus 50c postage and packing, from Rowse Muir Publications Ltd, 3 Percy Street, London W1

EXTRA COPIES of DATA SHEETS and REACTOR DRAWINGS published in NUCLEAR POWER can be obtained price 6d. each post free, from Rowse Muir Publications Ltd, 3 Percy Street, London W1.

Nuclear Power
The journal of British nuclear engineering

BACK NUMBERS

We receive repeated requests from readers who, for one reason or another, have been unable to obtain copies of the earlier issues of this journal.

A few copies of issues Nos. 2—10 are available for those who may wish to complete their files.

The price per copy is 3/6, including postage.

NUCLEAR POWER
3 Percy Street
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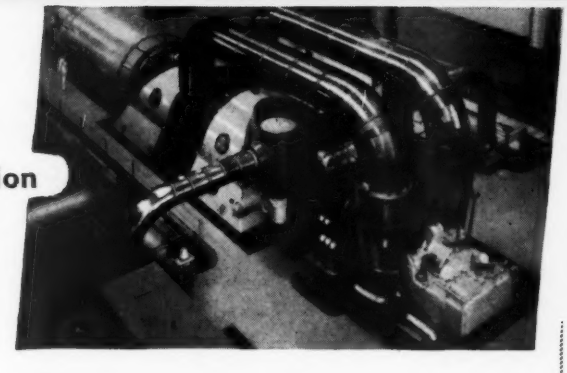

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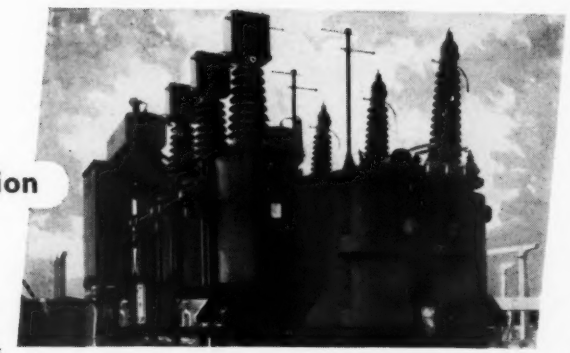

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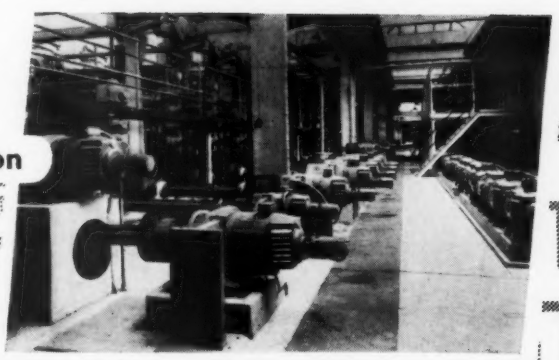

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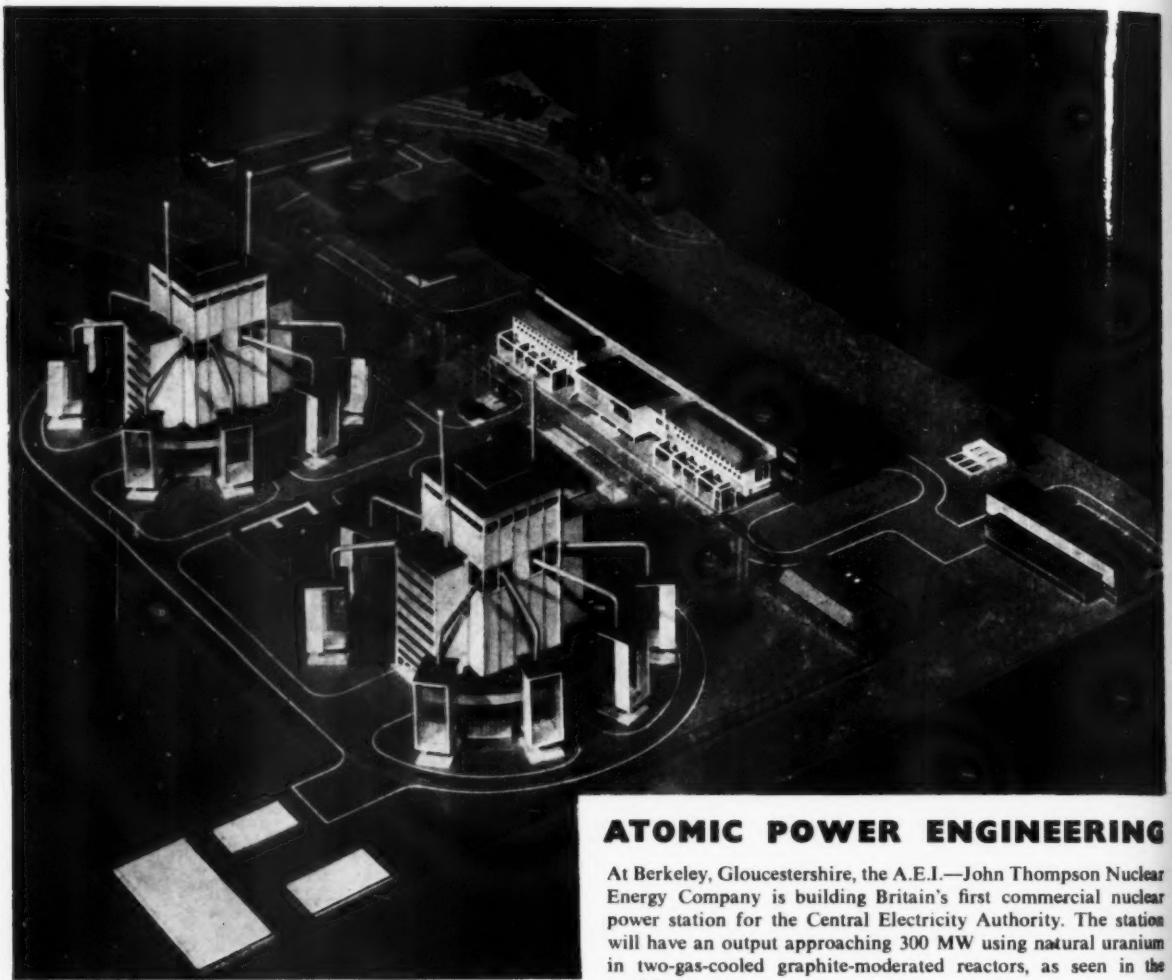

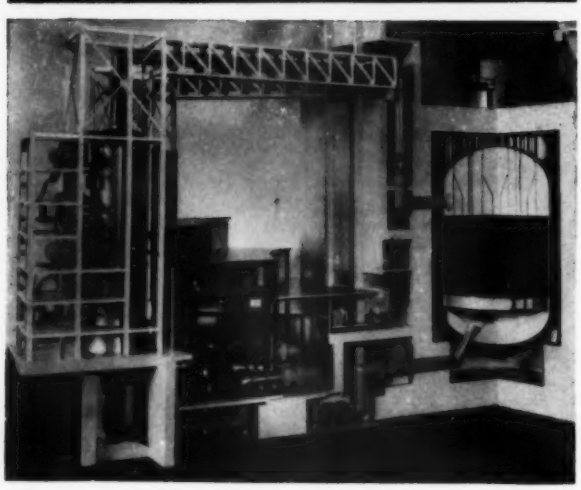

ATOMIC POWER ENGINEERING

At Berkeley, Gloucestershire, the A.E.I.—John Thompson Nuclear Energy Company is building Britain's first commercial nuclear power station for the Central Electricity Authority. The station will have an output approaching 300 MW using natural uranium in two-gas-cooled graphite-moderated reactors, as seen in the model above.

John Thompson are constructing the 1,000-ton reactor vessels of 3 in. steel, the fuel handling machines, gas-cooling circuits, the sixteen large heat-exchange towers and the thermal shielding of 4 in. steel. 150 miles of tubes will be used in the heat exchangers alone.

The sectionalised model at left shows one reactor and one of the heat-exchange circuits.

Since the earliest days of nuclear experimentation, John Thompson have produced the requisite plant. For the Ministry of Supply and later the U.K. Atomic Energy Authority they have executed work to exacting standards at Springfields, Windscale, Harwell, Capenhurst and Dounreay. With Associated Electrical Industries in the A.E.I.—John Thompson Nuclear Energy Company, formed to produce atomic power plant for the world, they are producing research reactors for the Atomic Weapons Research Establishment, and for the West German Government, and now the first full-scale commercial station for the Central Electricity Authority.

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